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GENETIC PSYCHOLOGY MONOGRAPHS

Child Behavior, Animal Behavior, and Comparative Psychology

A COMPARATIVE STUDY OF A GROUP OF SOUTHERN WHITE AND NEGRO INFANTS*

From Teachers College, Columbia University

By

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I

INTRODUCTION

Although unadulterated Negro racial characteristics cannot be determined through studies of the American amalgam, and although it is impossible to select the pure-bred Negro from the American Negro population for specific study, much can be gained from an accumulation of data concerning the characteristic traits of the *American Negro as he functions in the social organization* of the country, and in time theories substantiated by quantitative evidence may supersede those based upon pure prejudice. Prior to the Civil War and for some time following, the inherent inferiority of the Negro was an undisputed dogma. Within recent years the subject has been the topic of many investigations of a scientific or pseudo-scientific character. Ferguson *(33) has said, "One would not be far wrong in saying* that all experimental work done on the psychology of the Negro prior to 1900 is of practically negative value." Since that time, however, the increment of literature on Negro characteristics and differentia is boundless and ever aggregating. The only justification for this is that each investigation approaches the problem from a slightly different point of view, with slightly *different controls, and with recognized limitations.*

An inspection of these more scientific investigations as well as the popular treatises will, however, throw the student of racial differences into a mental pandemonium. Because there are inevitably so many variables, any study of racial differences is subject to op-

position and adversative interpretation. Viteles (116), having reviewed much of the recent literature, suggests that, "From among these varied conclusions it is possible for anyone interested in the problem of Negro-white differences to choose one which best suits his particular bias."

Since Ferguson in 1916 (33), Peterson in 1923 (88), and Klineberg in 1928 (64) have so adequately reviewed the literature prior to their publications, it would be superfluous for the writer to recapitulate, or critically to evaluate the previous studies, except to point out some of the more divergent, yet equally convincing, theories and hypotheses now extant. Different writers, interpreting the same body of data, will arrive at virtually opposite conclusions. Both may be very convincing. Take, for illustration, the many theories and speculations which have evolved relative to the general intelligence of the American Negro based upon an interpretation of the Alpha and Beta test scores made by the different groups of men in the army during the War. Brigham (17) reports that less than 12% of the Negroes exceed the average for native-born white draft; and on the strength of this he unequivocally avers that there is a distinct racial difference between the American Negro and the white in general intelligence. He admits that "The army tests showed the Northern Negro superior to the Southern Negro and this superiority is attributed to superior educational opportunities in the North." But, in his opinion, the superior intelligence scores of the Northern Negro are due to three factors: "(a) amount of educa-

tional opportunity; (*b*) *a greater amount of admixture* of white blood; and (*c*) the operation of economic and social forces, such as high wages, which tend to draw the more intelligent Negro to the North." This selective factor he would concede to be of greatest significance and is convinced that the difference cannot be explained adequately in terms of dissimilarities in educational and social opportunities. Bagley (5), interpreting the same data, attacks Brigham's position, saying, "On pages 724-5 of Army report, tables distribute by state the scores of the literate negroes on Army Alpha. After computing the medians one finds that the literate negroes from Illinois not only surpassed the literate negroes from the South, but also achieved a median score about the median score of the literate whites from the Southern states, indicating the effect of schooling on intelligence." Ferguson (35), on the other hand, finds that the median score attained by the Negroes on Army Alpha is inferior to that of the *mountaineer white*.

Studies of racial differences arise from a specific and practical need of adjusting educational systems and social and economic institutions to groups of people who are apparently different from the dominating and controlling group. It is quite natural, then, that the primary considerations should revolve around the question of intellectual capacity, the plasticity and modifiability of the group to be studied, or, in other words, the general intelligence of the group. It is equally natural that the earliest attempts to measure mental capacity of different races would be in terms of neurologi-

cal structure, the size, weight, and shape of the brain. Mere reference to the work of Bean (10), Mall (75), and Hrdlička (61) is sufficient to demonstrate the inadequacy of such methods in determining racial differences in intelligence. Furthermore, intelligence *per se* began to be interpreted more in terms of functions than structure, and with the development of intelligence tests new theories and new problems were introduced into the study of racial differences. Aside from the colossal data gathered from the Army Alpha and Beta scores, many experiments have been conducted using the several revisions of the Binet, Yerkes Point Scale, Myers Mental Measures, and various types of group or individual tests, verbal and non-verbal, abstract and performance tests, as instruments of measurement. Ferguson (33) used Woodworth-Wells Mixed Relations I and II, the Ebbinghaus Completion, a cancellation test, and a Columbia maze test for examining white and Negro public school children. On these tests he found that the performance of the Negroes is only 75% as efficient as that of the whites. Strong (104), having examined 350 white and colored children by the Goddard Revision of the Binet-Simon Scale, reports that twice as many Negro children show retardation in mental age as do white children. The colored children in the schools of Oklahoma City, according to Lacy (66), have apparently less of the "abilities measured by the Binet and Otis Self-Administering than do the white children of the city or the white children throughout the country." After giving the National Intelligence Test to 1272 children in Dallas and Fort

Worth, Garth and Whatley (40) report the average IQ of the Southern Negro to be 75, and the average disparity between real and mental age is 2.6 years. Price (96), studying the intelligence ratings given Negro and white freshmen in Negro and white colleges, respectively, finds that the difference in median score was ten points in favor of the whites, and that 20% of the Negroes reach or exceed the median of the whites. Baldwin (7), examining delinquent girls, both white and colored, at the Pennsylvania reformatory, states that the Negro girls accomplished only 62.4% as much work on a substitution test as the white girls, and that they made 245.3% more errors. Thorndike (112) concludes from the intelligence scores of colored and white high school pupils, that, "Less than four percent of the colored passed the median white score for the corresponding grade: and this percent would be a little decreased if the two tests were increased to an infinite number." Peterson (88), having applied group tests to six different school systems from the Southern states, says that, "About 83 percent of the whites are more efficient than the Negro of median ability, while only 15 to 18 percent of the Negroes reach the white median ability. The difference seems to be greater than this when stress is placed chiefly on the more abstract logical relations."

Other studies might be quoted but these seem sufficient to illustrate a considerable body of data predicating white superiority in greater or less degree. Notwithstanding the preponderance of evidence favoring white superiority, many writers admitting the quanti-

tative differences, nevertheless, take issue with these tenets and attribute the averred differences to extra-racial factors. Reuter (100), for example, states that "the differences found to exist between Negro and White, are subject to a more immediate, complete, and adequate explanation on the grounds of a difference in education and educational opportunity. . . . The idea of a racial inferiority and superiority is not a present problem of research among students; it is a matter of debate among laymen. For approximately two decades there has been virtual agreement among scholars; all accept as a provisional but fairly well founded working hypothesis the position that the various races and peoples of the world are essentially equal in mental ability and capacity for civilization." Then Thompson (111), whose statements are pregnant with emotion, contends: "The doctrine of inherent mental inferiority of the Negro is a myth, unfounded by the most logical interpretation of the scientific facts on the subject produced to date. . . . The mental and scholastic achievements of Negro children, as compared with white children are, in the main, a direct function of their environmental and school opportunities rather than a function of some inherent differences in mental ability." Gregg (48), judging the degree of skin pigmentation of a number of valedictorians and salutatorians at Hampton Institute, and finding as many dark as light Negro students so honored, says, "It is evident in so far as color may indicate the degree of white or Negro blood, it signifies little or nothing with respect to intellectual ability." Reinhardt (98) claims that

fossil remains give no support to the white man's claim to superiority; that living representatives of the two races do not prove Negro inferiority; the army and other intelligence tests do not show that the Negro is inferior; and that the preponderance of evidence is on *the side of superiority of opportunity rather than superiority* of inborn race equipment. Nutting (84) believes the inadequate performance of American Negroes is best explained in terms of "inferiority complex." Others recognizing measured differences in studies of Negro-white characteristics, but not admitting a real difference, attribute the measured difference to some factor in the test situation, the disadvantage of a colored man on being tested by a white man, the construction of the tests being the handiwork of white men, and to unavoidable factors of selection of subjects, etc.

More cautious students of racial differences between whites and Negroes have avoided generalizations relative to intellectual endowment and have attempted to analyze these differences into more specific traits, either mental or temperamental. It is frequently claimed *that the Negro is at a disadvantage on the ordinary in*telligence test because his time of performance is slow, *and many tests are rigidly scored on a time basis.* The importance of speed as a measure of intelligence is in itself a matter of contention among psychologists. Highsmith (59) says that the rate of response is not a reliable measure of intelligence. Peak and Boring (87), on the other hand, believe that "Speed of reaction is an important, and probably the most important

factor in individual differences in the intelligent act. We find these differences in speed are not due to gross distractions or irrelevant acts, but inhere in a single item of an intelligence test, and probably in so simple an act as the muscular reaction." However that may be, insofar as speed may be a factor in testing and interpreting racial differences, there are several quantitative studies from this angle. Peterson (91) says, "Many of the available tests, especially group tests are of such nature that the scores are considerably influenced by certain cultural 'sets' or attitudes; such as habitual slow rate of work, carelessness about accuracy, tendency to skip hard items in the test and therefore to waste time in finding the easy ones (practices seemingly common among negroes). . . . Individuals are moved not only by present contacts and stimuli as mere physical objects, but they gradually build up 'sets' or attitudes from contact with many situations whose effects are somehow carried over and become organized into more or less permanent tendencies of the kind mentioned. . . . These matters should not be overlooked in race testing. Differences obtained by means of tests, if these factors have not been equalized with the greatest care, cannot be set down uncritically as native differences." The most recent study of the effect of speed of performance in interpreting racial differences is that of Klineberg (64) whose results from experiments with white, Indian, and Negro children indicate that, "Superiority of White over Indian and Negro children in performance tests is largely, if not entirely, a superiority in scores for time. There is no

superiority, and in some cases an inferiority, in the scores for accuracy of performance. . . . There is evidence that the greater speed of performance of White children, which is responsible for the better scores for time is more probably determined by environmental than by racial differences."

Since it is frequently claimed that Negroes do better in rote memory or when dealing with practical concrete problems than when responding to more symbolic situations, many experimenters have essayed to break "intelligence" up into more elemental aspects for purposes of racial comparisons. Derrick (31), studying college students above the age of 16 years, says that "the negro is better in memory and concrete routine problems than in those involving mental abstraction." His findings were substantiated by Schwegler and Winn (101) who studied children of the seventh and eighth grades. The instrument of measurement was the Stanford Revision of the Binet, and they find the whites superior in tests of abstract reasoning, and recognition of ideas, whereas in rote memory and verbal facility the two groups were on a par. In tests of practical, common-sense adjustment, such as the ball-and-field test of the Binet, the Negroes are in their opinion equal to the whites. Peterson (90) finds the Negroes equal to the whites in retention and memory, but inferior in speed and reasoning. Sunne (107), on the other hand, notes a greater disparity between a group of white and Negro children on the National Intelligence Tests on the strictly linguistic items, and concludes that the Negro is not superior to the white in verbal reproduction.

Measurable differences in the performances of white and Negro groups is frequently attributed to temperamental differences rather than to differences in mental capacity. Although the instruments for measuring character traits are still unrefined, several attempts have been made to estimate characteristic trends of the two racial groups. Bond (16), having given the Pressey X-O and the Downey Will-Temperament group tests to 175 Negro adults, finds no distinctive pattern typical of a group profile. McFadden and Dashiell (77), who studied the volitional patterns of white and Negro high school students by means of the Downey Will-Temperament Test, conclude that the Negro is slower in movement than the white, less flexible, is quicker in making decisions, motor impulsions slightly greater, carries a slightly greater load of inertia; reacts more firmly against contradiction; offers less resistance to physical opposition; takes about the same or slightly less time in reconsidering his decisions; has about the same amount of interest in detail; less ability in coordinating impulses, and a slightly less tendency to volitional perseveration. Crane (25) set up a laboratory experiment for estimating the differences in inhibitions of the two groups. Having concluded from his results that inhibition tends to be a simpler process among the blacks than among the whites, he pictures the following situation which is illustrative of his interpretation of the Negro temperament in this respect: "Consider the situation of a white and a colored man in an elevator accident in which the car suddenly started to drop toward the bottom of the shaft with an accompaniment

of more or less noise. It does not seem unwarranted to predict that the colored man would immediately give vent to his instinctive reactions, whatever they might chance to be, after which if he escaped without injury he would be comparatively calm. The white man, on the other hand, would have more to contend with within himself and, though exercising greater control would probably exhibit just about as much instinctive behavior as his colored brother. Though the colored man might pick himself right up and walk off as though nothing had occurred, the white man would probably be all 'flinchy' for a considerable time to come."

There have also been a few studies of the specific abilities of Negroes, such as musical or mechanical ability. The instrument usually employed for the measuring of musical talent is the Seashore Victrola records. Gray and Bingham (47) took a group of trained and a group of untrained Negroes matched with a group of trained and untrained whites and a group of trained mulattoes, in their investigation of the musical ability of colored and white in the public schools. According to their results the Negroes in the untrained group show a superiority over the white untrained group in pitch and memory. On the other tests the whites show a superiority. Of the trained groups, the whites show a superiority in eight comparisons, and the mulatto shows a superiority to the Negro trained group. On the strength of these findings they conclude that there is a high correlation between musical score and an index of brightness. Yale Nathanson (83), re-

porting an investigation by Guy B. Johnson of 3500 persons in the graded schools and colleges of North Carolina in which he used the Seashore tests, supports Johnson's opinion that "the only absolute racial advantage which the Negro possesses above the Caucasian is in vocal ability . . . the Negro voice on the average is superior to the white voice, but this is due to an anatomical difference between the races in the organs of vocalization and does not reflect a superior musicality. . . . If we accept this superior vocal quality of the Negro voice there are no significant inborn differences in musical talents between the two races."

No attempt will be made in this chapter to evaluate these investigations in terms of procedure, conclusions, or interpretations. They are sufficient, however, to illustrate the chaotic opinions extant relative to racial differences as evidenced in the American Negro and white races. The cautious experimenter must so qualify his conclusions that they cease to be convincing; and the more dogmatic writer fails to offer supporting evidence of sound quality. Any investigation of racial differences in terms of white and colored traits is clouded by two factors: (*a*) admixture of white and Negro blood, and (*b*) the effect of environmental factors. Since it is impossible to control or rule out these variables, enlightenment upon the subject must depend upon an accumulation of evidence from various investigations, each controlling or measuring a different aspect of the problem.

Herskovits (53) has made some brave attempts to interpret Negro intelligence in terms of the amount of

Negro blood. Assuming that any distinctly racial characteristic will correlate in degree with the purity of blood of the particular race, he has conducted extensive and intensive researches to measure racial differences thus indicated. His criteria for "amount of Negro blood" were based upon complete genealogies plus physical measurements of (*a*) pigmentation, (*b*) width of nostrils, and (*c*) thickness of lips. Correlating the scores of college students on the Thorndike College Entrance Examination and the amount of Negro blood as so determined, he concludes: "We are forced to recognize that the relationship between test scores and physical traits denoting greater or less amounts of negro blood is so tenuous as to be of no value in drawing conclusions as to the comparative native ability or relative intelligence of the negro when compared to the white." Since it is so difficult to determine the degree of purity of blood in Negro subjects, most investigators have contented themselves with the social definition of the word; others have attempted to classify their subjects according to skin coloration. The method used in determining the percentage of black has varied—some using nothing more than the judgment of observers, others applying one or more of the several laboratory techniques which have been developed for the purpose. The most common of these methods are: (*a*) the Broca scale; (*b*) the Von Luschan tinted glass; and (*c*), the most practical of all, the color top. None of these are infallible, but the color top seems to offer the greatest reliability. Albeit, if skin pigmentation were precisely measured, the

extent to which it alone may be relied upon to indicate Negro heritage is yet another question. Todd and Van Goder (114), who used the color top in determining the black pigmentation in the skin of Negroes, say that the percentage of black pigmentation in the skin of Negroes cannot be called upon as a race distinction. Some brunettes of white stock have as large a percentage of black as many Negroes. Furthermore, the unaided eye is no judge of the percentage of black pigmentation. Davenport (26) ably points out the fallacy of using skin coloration as evidence of the amount of Negro blood in a given individual. After all, it appears that in the human species the determiners of skin coloration are linked with not more than 4 of the 48 chromosomes, and the determiners of the other 44 would have no association with that of skin pigmentation. He further adds: "Black skin color and woolly hair are closely associated in the pure-bred negro, but association is, so to say, accidental. The determiners for the two traits dissociate in the germ cells of the hybrids and reappear in the next generation in all possible combinations. . . . The fact that at least two of the negro's traits are inherited independently opens the way for some interesting considerations of a social nature. As is often the case, we have let one character, skin color, epitomize the totality of the racial characters of the group."

The dilemma of the student of Negro characteristics is therefore self-evident. Since there is no feasible method of establishing purity of stock as the Negro is known in this country, the results of any experiment

are, to that extent, subject to interpretation in terms of inheritance of white blood, and *a priori*, white characteristics. Herskovits (53), doubting the validity of the 1920 Census report, contends that approximately 80% of the Negro population of the United States represents a greater or less degree of mixture of white blood. But he purports to find, notwithstanding this miscegenation, marked homogeneity of physical traits in the American Negro, and he believes that by virtue of this admixture the American Negro is a type distinct from the white race with which he is amalgamated and equally distinct from the pure-blood African from which he is sprung.

A purely Negro racial study might be conducted on subjects born in darkest Africa, but such a study would be of little practical value in adjusting the American Negro, not the African Negro, into an American society. If, as Herskovits claims, the American Negro is a distinct type, then to generalize from studies of pure African subjects, assuming that such studies were feasible, would lead to more fallacious practices and theories than those now existing.

To control or eliminate the effect of environmental variables is practically as difficult as controlling the amount of white blood in Negro subjects. "Environmental factors" cover a multitude of discrepancies: inequality of opportunity; educational inequality; cultural inequality; language handicaps; difficulties in selection of subjects, etc. Garth (38) says, "The elements in a study of racial mental similarities or differences must be these: (*a*) so-called races R_1 and R_2,

(*b*) an equal amount of educational opportunity *E* would include social pressure and racial patterns of thought, and (*c*) psychological tests *D* within the grasp of both racial groups. We would have as a result of our experiment R_1ED equal to, greater than or less than R_2ED." Garth's experimental requirements cannot be achieved, but, as has been said, much may be learned by means of qualified and modified experimental procedures.

Restricting age limits of the subjects in an experiment is one method of qualifying experimental conditions. The youngest Negro children who have served as subjects for comparative studies in previous investigations were at the age of five and six years. Strong (104) compared white and colored children from six to twelve years of age. She finds that the colored children in the first five grades make a better showing than they do in the first seven. She used a revision of the Binet for measuring these children, and the following table taken from her report shows the distribution of children at each age rating below, at age, or above age.

Age (years)	Below age White	Below age Colored	At age White	At age Colored	Above age White	Above age Colored
6	19.4%	40.0%	30.6	33.3	50.0	27.7
7	13.9	29.4	61.1	58.8	25.0	11.8
8	18.5	23.0	55.5	38.5	26.0	18.5
9	32.2	71.4	41.9	21.4	25.9	7.2
10	55.1	75.0	27.6	12.5	17.3	12.5
11	34.6	43.7	42.2	50.0	23.1	6.3
12	67.5	77.0	32.5	23.0	...	...

It is easily perceived that the largest percentage of colored children test below age at years nine, ten,

eleven, and twelve. On the strength of these findings of Strong's, Bruner (18) suggests a more rapid rate of maturation for the colored children. Arlitt (2), examining Negro children from five to fifteen years of age by means of the Stanford Revision of the Binet Scale, contends that, "Age has an effect on Median I.Q. of negro children which it does not have in the case of native born whites. Actually very young negro children, five or six years old, have a median I.Q. of 100, or average for the average social status group, or seven points above that of the whites for the same social status, while negroes 10 to 15 years old have a median I.Q. of 78.9." Her contention is founded upon a study of 243 Negroes from five to fifteen years of age, 54 of whom were five or six years old. She classified them into social groups according to occupation of the father and then compared them with the norms established by Terman for children of certain social strata, as determined by occupational classification according to the Taussig scale. The children aged five and six were selected largely from a Negro playground; many of the others were chosen from Negro schools. Although Arlitt admits that this fact may have facilitated the selection of a higher type of child at the younger ages, since the more energetic ones would perhaps go to the playground, and although she recognizes more tests of the rote memory type (on which Negroes supposedly do well) at the lower age levels of the scale, and a greater number of language tests at the upper end of the scale (on which Negroes seem to do poorly), she nevertheless concludes that the effect

of age upon the median IQ of the Negro child is a distinct racial difference. Other writers seem to infer, though less explicitly, that Negro children at the younger age levels more nearly approach the norms of white children. Murdock (81) finds that at nine and ten years of age, chronologically, the median score of Negroes on the Pressey Group Test is approximately the same as that of the whites, but that at each succeeding chronological age the Negro median becomes lower and lower in comparison with that of the American white child. Witty and Decker (117) imply from their study on the educational attainment of Negro and white children that Negro children mature more quickly than white children, since the younger children tested on the Stanford Achievement more nearly reach the status of the white children than do the older ones.

Undeniably some of these studies lend support to the popular notion that the Negro child in infancy and early childhood develops more rapidly than the white child though he attains his maximum development much earlier and on a lower level. This idea seems to be a corollary to the theory that prolonged infancy is correlative with the higher species of animal life. If such an hypothesis be true, then Negro infants might be expected to show an acceleration in developmental traits common in infancy.

Modern psychology attaches considerable significance to the diagnostic and prognostic importance of early developmental trends. Gessell (41*a*) says, "Although we cannot say to what extent the infant stamps and makes the way, we may safely believe that the more

fundamental life characteristics of the early ontogenetic stages will also be found in the late stages. . . . The infant grows, the child grows, and also the youth and the adult. There must be some essential continuity in this growth. The growth characteristic of the infant must therefore prefigure in some ascertainable manner the growth characteristics of maturer years and even behavior traits of those years." While the significance of early developmental traits is not unquestionably established, there are many suggestions that such characteristic patterns have predictive value. Bühler and Hetzer (21) state that "in so far as pathological backwardness is a matter of very low learning ability, we were able to observe it as early as the middle of the first year." In the light of these tenets, a racial study based upon the reactions of infants offers a new aspect to the problem of Negro-white differences.

The preponderance of quantitative evidence to date seems to favor a slight superiority on the part of whites when compared with Negroes in mental performances. The extent to which these measurable differences are innate or environmental is still a matter of debate. There is also some experimental evidence, and more of theoretical hypothesis, to the effect that the amount of difference between white and colored groups increases materially with age. The vulnerable point with most of these studies lies in the standard for selecting subjects. If, for example, in the case of school children, they are selected according to grade, then chronological age becomes an outstanding variable; if they are chosen in terms of chronological age, then the amount and kind of schooling present disparity. Language is

another item making for inequality in the testing of older groups. Peterson (90) has averred that language is an important factor in the examination of Negro subjects. The same word, although comprehended, has a different connotation for the Negro child and therefore modifies his mental set toward the test situation. For example, "as fast as you can" may mean one thing to the Negro child and another to the white child. In testing infants neither group of subjects can profit or lose because of language differences. Certainly, insofar as a racial study is concerned, many of the conflicting and extraneous factors which loom large in an investigation of school children or adults may be obviated or minimized if the age limit of the subjects is restricted to the period of infancy. Furthermore, minor details which may facilitate marked inaccuracies in the testing of older children, such as obtaining an inaccurate date of birth, are lessened in the examination of infants. (Negro mothers frequently cannot give the exact date of birth of their children and in such instances they are prone to guess. If the child is less than a year old the chances of getting an accurate birth date are greatly increased.)

As previously stated, the presence of extraneous and variable factors in any study of the characteristics of the American Negro preclude indisputable conclusions. The present investigation makes no pretense of having eliminated these extra-racial factors, but in restricting the age limit of the subjects, many such difficulties are automatically curtailed, and the study therefore offers a new approach to the study of racial differences.

II

THE PRESENT EXPERIMENT

The present experiment was conducted at Tallahassee, Florida, a fairly typical Southern community of approximately ten or twelve thousand population, about fifty per cent of which are Negroes. (The terms "Negro," "colored," and "blacks" will be used interchangeably in this study, denoting the social concepts of the words. That is to say, the terms include anyone who is reared a Negro and socially accepted as such, irrespective of the amount of white blood that may or may not be present.) The community is especially suited as a field for racial study. The population, both white and colored, is remarkably stable, which suggests that both groups have been subject to the same climatic influences and variations for generations. The South is recognized as a section of "pure Anglo-Saxon" blood, and in this particular community there is practically no foreign-born white element. The parents of the white babies in this investigation are in every instance American-born, usually for several generations. The birth rates of whites and Negroes for 1927 and 1928, as quoted by the Bureau of Vital Statistics, are approximately the same with a slightly greater number of whites born during those years than of Negro babies. There are separate public schools in the community for white and colored. The city is an important academic center of the state for both groups. Florida State College for Women (for whites) is located there and

also the State Agricultural and Mechanical Arts College for Negroes.

The community appears to be a rather typical Southern community, and the babies selected for this investigation are quite representative of the two groups as they are found in the city. About fifty per cent of the babies born within the year—both white and colored—figured as subjects in this comparative study.

There are several considerations operating in the choice of subjects for this investigation. Obviously, restricting the life age of the subject is, to that extent, limiting the effect of environmental factors. The question then becomes: what is the lowest age level at which distinctive measurable differences may be obtained and at the same time reduce the effect of environmental influences to a minimum value. Of course, the period when the individual is least subject to social or environmental factors is the neonate period, but unfortunately the prognostic value of reaction patterns at that level has not been so well determined as at a later age. There are a few recent studies which suggest the level at which the individual's reactions are correlated with certain specific and immediate environmental and family relationships. Goodenough (44), investigating the relationship between intelligence of preschool children and the occupational classification of their fathers, finds that, "marked intellectual differences between social classes are well established by the age of two, three, and four years . . . . and the differences in environmental stimulation have no cumulative effect, at least after the age of two years . . . ." Goodenough

used the Kuhlmann revision of the Binet Scale for her study, and, apropos of a discussion of the simplicity of the test situations at the third year level, she further concludes: "The fact that children of different social classes show as great differences in their performances of these extremely simple tasks as they afterwards manifest in regard to the relatively complex problems of later life, lends support to the theory that under ordinary conditions of modern life, variations in mental growth are more directly dependent upon innate factors than upon differences in post natal opportunity and stimulation." In conjunction with the same experiment she studied the relationship of the intelligence of the preschool child to the education of the parents and found a positive correlation ranging from .264 to .353 between the Kuhlmann-Binet rating of the child and the education of the parent. While her data show a positive relationship between the education of the parent and the intelligence of the preschool child, they do not reveal a greater relationship between the intelligence of the preschool child and the education of the mother as compared to that of the father, in spite of the fact that the preschool child spends more time with the mother than with the father. Goodenough seems to infer from this that the correlation between parent education and intelligence of the preschool child is probably a resultant of inheritance rather than of sociological contact. In any event, the fact that there is no greater correlation between the education of the mother and the intelligence of the child than there is between the education of the father

and the intelligence of the child lends support to the minimum effect of social-environmental contacts on the testing of young children. Furfey (37), furthermore, finds no relationship between the socio-economic status of the parent as rated on the Chapman and Sims rating scale and the intelligence of infants as measured by the Linfert-Hierholzer Development Scale (72). Goodenough (45), in attempting to explain this discrepancy with her own findings, is inclined to believe that the Linfert-Hierholzer scale "does not measure exactly the same kind of ability as that indicated by the tests used for older children." However that may be, the Linfert-Hierholzer scale involves such test items as are commonly accepted indices of maturation and infant growth, and the study as such offers additional evidence of the minimal relationship of early environmental factors on the measurement of development in infancy. Gesell and Thompson (43), studying the performances of identical twins, suggest that not only are social contacts of relatively small consequence on the performance of infants, but that materials, practice, and exercise are comparatively inconsequential in altering the maturational cycle of the individual infant. These investigators meticulously and assiduously studied several performances of identical twins, using one as control while the other was subjected to training and practice. Their general conclusions point "consistently to the preponderant importance of maturational factors in the determination of infant behavior patterns. . . . There is no conclusive evidence that practice and exercise even hasten the actual ap-

pearance of types of reactions like climbing and tower building. The time of appearance is fundamentally determined by the ripeness of the neural structures." This again brings up the whole question of the predictive value of these early infant reaction patterns. To what extent they are related to or indicative of later mental performances (such as are measured by standardized intelligence tests) remains undetermined, and a discussion of that particular issue falls outside the scope of this study. It suffices for the purpose of this investigation to repeat that the trend of modern psychology is to place considerable importance on these early behavior patterns, no matter if they are maturational or acquired.

In the light of the foregoing studies, the age level at which environmental factors are minimized and yet quantitatively measurable differences obtainable would appear to be during the first year of life. So the subjects chosen for this study were Negro and white infants ranging in chronological age from two to eleven months, selected at random from the infant population of Tallahassee (that is, the method of selection was random and haphazard), though the same mode of choosing subjects was employed with Negroes and whites. It might be added that the social factors between a group of Southern white and Negro infants are somewhat equalized by the fact that many white infants spend much of their waking hours in the care of Negro nurses.

As mentioned above, the method of selecting the subjects was varied and haphazard. The first step

taken was to obtain the list of babies born in the community during the past twelve months recorded in the birth registry by the obstetricians and midwives. Letters inviting cooperation were mailed to the parents of these infants, but at least 80% were returned from the post-office marked "Insufficient address." There were several contributing causes for the inefficacy of this method in making contact with the parents: (*a*) names, addresses, and dates were frequently inaccurately recorded in the registry; (*b*) especially among the Negroes many of those addressed seldom, if ever, received a letter; were therefore unknown to the postman on the route, and, unless a definite house number was given, he could not locate them. (Many of the Negroes have no address more definite than the name of the "quarters" in which they reside.) And (*c*) the letters numbered about 250 and were therefore not given the individual attention a single letter would receive by the post-office authorities.

Another contact was made through the white and Negro obstetricians in the city who furnished the names of infants known to them. This was a reasonably productive source and usually elicited cooperation from the parents. It was, however, somewhat selective, since those who could afford a physician were obviously of the better social and economic classes, especially among the Negroes. A third source of information was made through the public schools—white and colored. The teachers supplied a list of names of those children in their classes who have "a baby in their home."

The most effective, and incidentally the most ludicrous, method was a sort of house-to-house canvass. The writer and assistant would drive through the community watching for diapers on the line or any other known insignia of an infant in the home, or they would approach passers-by and ask if they knew of babies in the neighborhood. The usual horde of Saturday afternoon shoppers in a small town brought the customary cargo of infants, and the price of securing them was just enough bravado to approach the shop-worn mother, make the proper remarks on the attractiveness of the crying infant in her arms, explain one's general and specific interest in babies, and thereby sell to her the idea of "loaning" her child for the experiment. The local Ten-Cent-Store was a strategic location for such "baby pick-ups."

With some of the mothers, notably the Negroes, it required something more tangible than taking part in an experiment to educe her cooperation. She was therefore offered the advantage of having her baby weighed and measured and was promised a kodak picture of the child as an additional inducement. The details involved in securing subjects are reported merely to demonstrate that the method of selection was "random." The same method was employed in contacting both white and colored subjects.

Although the subjects were selected at random and the results for both white and colored yield a normal distribution in terms of "Developmental Quotient," the educational levels of the parents tend toward the upper grades, high school, and college levels for both

white and colored, though the educational classification of Negro parents shows greater variability. The educational classification of the parents according to the mother's report is revealed in Table 1, though this classification is subject to some error since the Negro mothers would often "guess" at the grade achieved, especially when reporting the educational level of the father. Furthermore, in view of the great amount of

TABLE 1

THE HIGHEST EDUCATIONAL LEVEL ACHIEVED BY EITHER ONE OF THE PARENTS

Grade	Colored	White
Second	4	
Third	5	
Four	5	1
Fifth	8	1
Sixth	11	
Seventh	1	6th 7th 8th 11
Eighth	1	
High school	8	18
College or normal	11	30
Undetermined	6	
	60	68

THE HIGHEST EDUCATIONAL LEVEL ACHIEVED BY THE MOTHERS

Grade	Colored	White
Second	6	
Third	3	
Fourth	5	1
Fifth	12	
Sixth	7	2
Seventh	1	2
Eighth	1	5
High school	12	24
College or normal	5	24
Undetermined	8	10
	60	68

illegitimacy and promiscuity among the Negroes, it is questionable if the Negro mothers could in every instance identify the father of the child.

These figures are in answer to the question: "In what grade were you when you left school?" The data, as classified, are somewhat misleading, for if a parent spent four weeks or four years in college he was placed with the "college" group. But the figures are too small for more refined classification. The surprisingly large number of those who fall in the "college or normal" group both for the colored and the white is probably explained by the presence of a white and also a colored college in the town. However, it should be borne in mind that since the Negro college was a college of agriculture and mechanical arts the term "college" is by no means equivalent for the two groups. There is another possible fallacy in the classification. Although some of the Negro mothers claim to have attended the second, third, or fourth grades, a more accurate classification for them would no doubt be "illiterate." In any event, very little significance is attached to these data, though they do suggest that there was a tendency to draw more heavily from the better educated parent for both the white and colored groups.

No attempt was made to classify the parents according to occupational level, since there is no adequate or even plausible criterion for equating the occupational classes of Negroes and whites. Nor was it possible to elicit reasonably accurate information from some of the Negro mothers relative to the occupation of the father. There are several rating scales in use for esti-

mating social and economic status of families, but none is applicable in judging the social level of Southern Negro homes, and to attempt to do so would be more misleading than justifiable in an investigation of this sort.

As stated above, the term "Negro" was accepted in the social usage of the word. This seems warranted in view of the fact that the "social" Negro is the American problem. Furthermore, there is, as yet, no reliable method of estimating, with unquestionable accuracy, the degree of white blood in an individual. To rely upon genealogies as given by the mothers is worse than worthless. It is a well-known fact that some life insurance companies refuse to insure Negroes because they cannot identify the line of heritage. The most common method is even less reliable with infants than with older children and adults. Davenport (26) in making an investigation of heredity in skin coloration excluded all subjects under two years of age on the ground that, "such individuals have not yet gained their full pigmentation; that in them melanic pigmentation is in an embryonic condition." Then, as was pointed out in Chapter I, skin pigmentation, if precisely measured, is *per se* no measure of the heredity of white or Negro blood.

All the infants in this experiment were examined within two days of the monthly birthday. Only infants reported by the mother as full-term pregnancies were included in this experiment. Experimental conditions were held constant for both groups. All examinations were made in the same examining room and by the

same examiners and with the same test materials. In order to establish a technique in administering tests, the writer and assistants examined approximately ten babies before any results were used for experimental purposes or for this investigation. Ordinarily the writer or an assistant went to the home and brought the child to the examining room for study. Occasionally the nurse, mother, or some member of the family accompanied the infant. More frequently the baby was unaccompanied by anyone from the home. No attempt was made to control the presence or absence of the mother in the examining room. If the mother desired to be present she was allowed. The only question was one of rapport, and every effort was made to obtain the maximum rating of the infants. In one or two instances when a complete rating could not otherwise be obtained the presence of the mother was requested. This situation was individual and not racial. About as many colored mothers were present during the examination as there were white mothers.

Records were included in this study only if examiners felt rapport was well established and that the baby was examined under optimum test conditions. Sometimes it would take two or more appointments in order to obtain a maximum rating of a given child. In some instances the baby was allowed to sleep or was given food in the examining room by the examiner in order to establish more complete rapport. It seemed better, in view of the huts in which many of the Negroes live and the innumerable curious children flocking around the homes, to test all the babies in the same room even

if it involved taking the child out of his familiar surroundings and placing him in a strange one with relatively strange adults. Taking them out of their own home had its advantages and disadvantages. In the first place, it held the conditions more constant for the two groups than would otherwise have been possible, but, on the other hand, even with very young babies a more complete reaction may be elicited when the child is in his familiar environment. The infants were brought to the examining room in an open automobile. For most of them this was a very pleasant experience —a pleasant experience which, at the outset, became associated with the examiner. Unfortunately, taking them out of the home required getting them "dressed up"—a process disagreeable to most babies. On the whole, however, the advantages of a constant testing room seemed to overbalance the disadvantages, and for that reason it was employed in this investigation.

The test equipment was of such material that everything could be thoroughly sterilized after each examination. This was done by prolonged boiling, or washing in a solution of bichloride of mercury, and exposure to Florida sunshine.

The infants were scored on a scale of "Baby Tests" compiled and standardized by Hildegard Hetzer and Käthe Wolf. A detailed description of these tests and the administration thereof will be given in the succeeding chapter.

There were always two persons active in the administration of the tests, one as examiner and the other as recorder. Some of the test items were extremely sub-

jective in rating. In any doubtful situation in the present investigation the rating was determined by the combined judgment of examiner and recorder, that is, a rating was marked failure unless both examiner and recorder agreed orally that the reaction was adequate. Ordinarily the response was elicited from the infant more than once. The writer's assistants in this experiment were four students from the advanced course in child psychology given by the writer at Florida State College for Women. One was a graduate student in psychology and another a graduate nurse; they were trained by the writer and assisted at intervals in the administration of the tests.

Such information as the following was obtained, usually from the mother, concerning the child's history: (*a*) age, (*b*) sex, (*c*) type of birth—full-term or premature, (*d*) father's occupation, (*e*) father's educational status, (*f*) mother's occupation if she works outside the home, (*g*) educational status of mother, (*h*) child's position in the family, number of sibs, etc. Many of these data are, however, of little value insofar as the interpretation of the results of this investigation is concerned, since the reliability of report is highly questionable. However, this is of relatively small importance because the weight of the investigation rests upon the immaturity of the subjects rather than upon an equation of social background.

The age level at which environmental factors are reduced to a minimum and measurable differences in performances of individuals are at the same age obtainable appears to be within the first year of life. Al-

though the relationship between early developmental reaction patterns and subsequent intellectual attainment is undetermined, the trend of modern psychology seems to attach considerable importance to these early behavior patterns. If these early behavior patterns in infants have diagnostic and prognostic value, then a racial study of these traits gains significance. In view of the extent of amalgamation of the Negro and the white races in the United States, and the impracticability of measuring the amount of heritage from one race or another in a given individual, the present investigation is based upon a comparison of American white infants with other infants who are socially accepted as "Negro" irrespective of their heritage of white characteristics. The investigation involves an examination of 68 white babies and 60 colored babies, ranging in chronological age from two to eleven months, selected at random from the infant population of Tallahassee, Florida.

The instrument of measurement used was the scale of Vienna "Baby Tests" and certain gross physical measurements. Experimental conditions were held constant for both groups as to means of selection and method of examination.

III

MEANS OF MEASUREMENT

Scanning the literature on mental measurements, one readily understands why the school child and the adult should be the selected subjects for racial comparisons. Reliable, standardized tests for these groups have been in practical and extensive use for some time. Although much attention has been focused upon the growth of the infant and the preschool child during the past decade, many of these studies have been of the longitudinal, biographical sort, and the development of standardized techniques of measurement for young children is still in its primacy. Perhaps the most colossal undertaking in the establishing of developmental norms at the early age levels is that of the Psycho-Clinic at Yale, under the direction of Dr. Gesell (41). These tests do not, however, constitute a scale. Linfert and Hierholzer (72) have a point scale standardized on 50 infants at each of the following ages: 1, 2, 3, 6, 9, and 12 months. Figurin and Denisoff (36) established norms of behavior on 100 institutional children and 100 well-reared children under one year of age. Kuhlmann (65*a*), in his re-standardization of the Binet, established norms for infants at the ages of 3, 6, 9, and 12 months. To evaluate or discuss the relative significance or reliability of these several tests or scales falls outside the province of this chapter, the purpose of which is to give a detailed description of the particular scale selected in this investigation as the instrument of

measuring developmental growth in infants under one year of age.

This scale of "Baby Tests" was devised and standardized by Hildegard Hetzer and Käthe Wolf (58), under the direction of Charlotte Bühler of the Psychologischen Institut in Vienna. The authors have attempted to embody within the scale test situations which, in combined form, estimate the maturity level of the child in the various aspects of typical behavior at a given age. The test items were selected from an inventory of activities compiled from a 24-hour observation on the behavior of infants at the different age levels. The aim of the scale is to get a total picture of the behavior of the baby at a given age, and for that purpose those situations stimulating responses most characteristic of the behavior of the normal child at a particular chronological age are included in the scale. These characteristic traits have been formulated by Karl Bühler (21*a*) as (*a*) the child's control of his own body, the development of coordinations in the reception of and defense to stimuli; (*b*) his gain in the manipulation of objects; (*c*) the infant's establishing of social contact; (*d*) early development of memory and imitation; and (*e*) the setting of goals and the achievement of objects. Of course any one particular test item may involve one or more of these several aspects of the normal maturation of an infant. The rather neat graduation of some of the test situations is best shown by illustration: The infant's growth in control over his environment is well demonstrated by a simple piece of cotton touched lightly to the nose. A

two-months-old baby will turn his head (avoidance); a three-months-old baby will wriggle his whole body (more vigorous avoidance); a seven-months-old baby becomes aggressively defensive and will push away with his hand the source of annoying stimulation. Or, to illustrate the steps through which the child will pass in establishing social contact: At four months of age an infant will gaze after an adult who leaves him; at six months he will try by cooing, seeking the eye, etc., to attract the attention of the ignoring adult; and by nine months he has become so aggressive in seeking social contact that he will pull at the adult's clothing.

The tests were standardized on 20 children at each month level. The allocation of a test at a particular level was determined by the percentage of children at a given age who passed the test. The range, according to their findings, during which a particular behavior trait might appear, covered just five months. That is, the time or age level at which the youngest child is able to achieve a particular performance to the age at which it would have been achieved by 100% of the babies extended over a range of five months. For example, according to the authors of the scale it was determined with 100 babies that the "manipulation of an object" was achieved:

in the second month by 5%,
in the third month by 30%,
in the fourth month by 65%,
in the fifth month by 90%,
in the sixth month by 100%.

The test was, therefore, placed by the authors at the

fourth month. A test was placed at a given age level if it proved too difficult for the median child one month younger. The allocation of the test items will be discussed more fully in connection with the method of scoring used in the present study and the interpretations of these results.

A detailed analysis of the test items and the method of administration (free translation) follow.

Materials needed

2 colored celluloid rattles	napkin
1 bright disc	rubber doll
1 shrill whistle	nest of 6 cubes
1 clapper	1 mirror
1 bell	1 picture book
1 mask	1 ball
cotton	1 box—2 covers—different sizes
cardboard cover	1 glass plate
1 screen	1 string
stop-watch	2 spoons

II. Two-Months Test

1. *Holding Head Erect.* The experimenter, by supporting the seat and back of the child with one hand, shoulders and head with the other hand, brings the child out of the horizontal into the vertical position. Then he carefully removes the support to the head, being ready to replace the support if the child cannot carry its head alone, letting it fall forwards or backwards.

   Successful reaction: Passed if the head is held erect by the child for several seconds.

2. *Holding Head Up When Lying Face Down.* The child is placed ventrally on a horizontal surface, so that the head lies securely between the two arms which are bent at the elbows. Generally, the child, in order to avoid the disagreeable contact of face with underlying surface, lifts up the head at once, without further interference of the examiner. If the reaction

does not occur spontaneously it is often provoked by introducing a sound stimulus toward which the child will turn, or by presenting a visual stimulus. One can knock on the table, whistle, or pass an object before the eyes of the child.

Successful reaction: Passed if the head is raised up from underlying surface.

3. *Searching, Turning of Head During a Continuous Sound Stimulus.* Half a meter away from the child, a rattle is shaken, not in line with the child's direction of vision. Examiner must be absolutely hidden from the child.

   Successful reaction: Turning of the head; the gaze generally remains fixed.

4. *Taking Fright at Loud Sound Stimulus.* The examiner, who cannot be seen by the child, vigorously claps his hands for 5 seconds or rattles for the same length of time a small child's clapper.

   Successful reaction: Passed if blinking of eyelids, distorting corners of mouth, wrinkling brow, twitching, and uneasy movements of entire body, making fists, crying, sounds of displeasure, screaming. (Only one or more of these reactions is necessary for a positive score.)

5. *Fixating.* A radiant object—a disc of 8-cm. diameter covered with tinfoil—is brought one and one-half meters from the face of the child and in his line of regard.

   Successful reaction: Rather long quiet looking, or staring, at the object.

6. *Flight Movements with Head.* With a bit of cotton or cellulose the examiner makes the movements of nose-cleaning on the nose of the child.

   Successful reaction: Turning away the head; disturbed turning of head to both sides.

7. *Social Reactions.* The adult steps up to the bed of the child, bends over, and tries to catch his eye. He remains in this position for one or two minutes, and then suddenly leaves the child.

Successful reaction: Cessation of crying which may have been going on before the adult appeared; intensive observation of examiner; crying when examiner leaves the bed. (Partial reaction suffices.)

8. *Reaction to Change in Pitch of Voice.* The examiner hides from the child and speaks in his normal voice to the child for 30 seconds. Then he suddenly starts muttering in a deep bass voice for 30 seconds. A high falsetto voice may be used instead.

   Successful reaction: Passed if blinking of eyelids, distorting corners of mouth, wrinkling brow, twitching and uneasy movements of the whole body, screaming, sounds of displeasure, crying, making fists, etc., appear. (A partial reaction suffices.)

9. *Babblings.* Cannot be provoked by specially introduced stimuli. Will probably appear spontaneously during the course of the examination.

   Successful reaction: Spontaneous vocalizations; reports of mother or nurse accepted as positive evidence.

10. *Experimental Movements.* Cannot be provoked by specially introduced stimuli. Must in all cases be observed by the examiner himself.

    Successful reaction: The appearance of slow, quiet movements, which the child himself observes, follows. One of their main characteristics is that one and the same movement is repeated a number of times by the child in exactly the same way.

III. THREE-MONTHS TEST

1. *Holding Head and Shoulders Up When Lying Face Down.* Procedure same as in II-2.

   Successful reaction: Head and shoulders are lifted up from underlying surface. Child supports itself on its lower arms.

2. *Feeling Objects.* A piece of cardboard (20 cm. x 10 cm.) is moved near the child in such a way that in one of its movements it touches the cardboard. If no cardboard is available, any other solid object can be brought near the child in the way described.

Successful reaction: The child strokes his flat hand over the cardboard several times, sometimes also with the clenched fist. The movement is slow and is observed by the child. This reaction can often be observed without the introduction of a special stimulus, if the hand of the child happens to come into contact with the sides of the bed or with the clothing of the examiner.

3. *Seeking Source of Sound with Eyes.* Procedure same as in II-3.

   Successful reaction: While sound continues the eyes are turned in all directions in a searching manner.

4. *Following Moving Objects with the Eyes.* A radiant object (Test II-4) is moved into the line of regard of the child. When the line of vision fixates on the stimulus, the latter is moved very slowly to the side and then past the head of the child to the other side.

   Successful reaction: The eyes of the child follow the moving object.

5. *Reaction to Disappearance of a Seen Object.* Procedure same as in III-4.

   Successful reaction: The child looks after the object which it had been following, and which is then suddenly removed, for several seconds, or else shows some kind of negative expressive movements (crying, wrinkling the brow, distorting the mouth).

6. *Changed Reaction to Repeated Stimulation.* The sound of a shrill whistle, or the deep bass muttering (II-3) are offered the child for 30 seconds. After a pause of 1, 2, and 15 minutes, the stimulus is repeated. The reaction time, i.e., the duration of the reaction from the beginning of the stimulation is always to be measured.

   Successful reaction: The reaction to the first stimulation is negative (cp. the reaction II-5). The reactions to the succeeding stimulations are shorter and less negative. Neutral reactions replace the negative ones in the later stimulus presentations.

7. *Flight Movements with the Whole Body after Tactual Stimulation.* Procedure same as in II-6.

Successful reaction: Turning away the head and other parts of the body. The arm and the pelvis usually remain quiet.

8. *Answering a Glance with Smiling or Babbling.* Procedure same as in II-7.

   Successful reaction: Smiling or babbling to the examiner.

9. *Experiment with Mask.* The examiner brings his face to within one-half meter from the child and looks at it quietly for 30 seconds. Then he takes an animal mask, which should not be colored too intensively—we used a brownish yellow rabbit head mask—and holds it before his face, remaining in this position for a little while.

   Successful reaction: Fright and negative reaction when the mask is used.

10. *Imitating Mimicry (imitating facial expressions).* The examiner brings his face very close to that of the child (20 cm.), and when the child looks at him "points" his mouth (pouts) and then pulls his mouth wide open again, repeating this alternation as long as the child continues to look at him.

    Successful reaction: Any attempt of the child to imitate the movements, either while the examiner is demonstrating them or after he has ceased in his attempts. The child often succeeds in making, not the same, but similar movements. This, also, is considered positive (success). The demonstration of the movements must often be continued for 3-10 minutes.

IV. Four-Months Test

1. *Lying Supported only on Hand Surfaces.* Procedure same as in II-2.

   Successful reaction: Head and shoulders and upper part of body are raised so far from the underlying surface that the child lies, supported only on the hand surfaces.

2. *Reaching for a Touched Object.* An object is held in such a way that the hand of the child comes into contact with it, but without the eyes following it.

Successful reaction: The actually experienced object is grasped.

3. *Grasping with Both Hands without Using Fingers.* A rattle is placed within reaching distance of the child, and its attention is drawn to the rattle.

   Successful reaction: The child reaches for the rattle with both hands, fists clenched or fingers outstretched; does not make use of the fact that in reaching one can close the hand.

4. *Handling and Moving About an Object.* A rattle is placed in the baby's hands. The hand holds the object tightly even though there had been no active grasping.

   Successful reaction: The child holds the object securely and moves it about with its hands.

5. *Looking at a Touched Object.* Procedure same as in III-3.

   Successful reaction: The child observes the object which it is handling.

6. *Active Looking About in a New Situation.* The examiner carries the child into another part of the room.

   Successful reaction: The child looks around in all directions in a lively and interested fashion.

7. *Napkin Experiment—Lying Down.* A non-translucent napkin made of fine-mesh material is placed over the face of the child.

   Successful reaction: The child kicks about vigorously and attempts to get rid of the napkin by rolling the body back and forth.

8. *Adult Playmate Leaves the Child.* The examiner busies himself with the child, plays with it, talks to it, and manipulates a rattle or rubber doll before its eyes. Then, suddenly, he leaves the child.

   Successful reaction: Expressions of displeasure or dissatisfaction, or looking after the examiner.

9. *Removing Toys.* A toy, which the child has been handling, is suddenly taken out of his hand. The duration of the reaction is measured with a stopwatch.

Successful reaction: Expressions of displeasure or looking after the toy (25 seconds long).

10. *Imitating Mimicry.* (III-10.) The demonstrated movement is wrinkling of the forehead. The examiner draws his forehead into horizontal and vertical wrinkles or folds. The movements must be repeated very often.

    Successful reaction: cp. III-10.

V. Five-Months Test

1. *Holding Head and Shoulders Up When Lying Down.* A radiant object, the previously described disc, or a mirror (15 cm. x 20 cm.) are brought near the bed, approaching from the foot-end of the bed, so that the reflection strikes the child in the eyes, and then the object is again moved towards the foot-end of the bed. If the child happens to be busied with a toy at the time this test is made, this toy may be taken away and moved towards the foot-end of the bed.

   Successful reaction: Head and shoulders are lifted up from the underlying surface.

2. *Turning from Back Position to the Side and Back Again.* A bell is sounded to one side of the child, so that the latter can see the bell, or else it is brought within reaching distance so that the child, by turning slightly to the side, can grasp it. The desired reaction often occurs without special effort on the part of the examiner, while the child is busied with this or that.

   Successful reaction: Turning of the entire body to the side. The problem is considered solved when the child has turned its pelvis.

3. *Reaching with One Hand after a Seen Object.* Procedure same as in IV-2.

   Successful reaction: The child grasps the object with one hand and closes its fingers around it. The problem is also considered solved if the child reaches with both hands and uses the fingers.

4. *Differentiating between the Friendly and Angry Expression of a Person.* The examiner bends over the child, nears his face to within 1/4 meter from that of

the child, and smiles and talks to the child for 30 seconds. Suddenly he changes his modulation, draws his forehead into deep folds, and talks angrily to the child.

Successful reaction: During the friendly expression, smiling and positive expressive movements. During the angry expression, negative expressive movements.

5. *Napkin Experiment—Lying on Back.* Procedure same as in IV-6.

   Successful reaction: The child reaches for the napkin and frees itself of it.

6. *Removing Toys.* Procedure same as in IV-8.

   Successful reaction: Expressions of displeasure, negative expressive movements; duration of reaction, 28 seconds.

7. *Defense When Toys Are Taken Away.* Procedure same as in V-6.

   Successful reaction: The child offers examiner resistance when the latter attempts to take away an object which the child is holding in its hands.

8. *Looking for a Lost Toy.* One observes the child when, incidentally, he has lost his toy, or one takes it out of his hand, without, however, using force as in the previous test.

   Successful reaction: The child turns his head in the direction in which the toy was removed and looks searchingly around.

9. *Positive Reaction to Clangs.* A bell is sounded close to the child. The examiner is hidden from the child.

   Successful reaction: Smiling and positive expressive movements.

10. *Imitating Mimicry.* The examiner bends down over the child and demonstrates sticking out and pulling in of the tongue.

    Successful reaction: Same as in III-10.

VI. SIX-MONTHS TEST

1. *Sitting with Support.* The examiner places the child in a corner of the bed and supports it by slipping a pillow behind its back.

Successful reaction: The child remains sitting upright.

2. *Edge of Table Test.* The examiner sits down at a table and takes the child on his lap in such a way that, by stretching out its arms, it can reach the table.

   Successful reaction: The child seizes the edge of the table with the hands and hangs on tightly.

3. *Displeasure after Vain Reaching.* As soon as the child reaches for the object, the latter is pulled away.

   Successful reaction: Crying or other negative expressive movements.

4. *Differentiating between Friendly and Angry Talking.* The examiner is hidden from the child. He talks to the child for 30 seconds in a friendly tone. Then he talks angrily to the child for 30 seconds.

   Successful reaction: Positive expressions during the friendly talking; negative expressive movements during the scolding.

5. *Manipulating a Still Object with a Moving One.* A rattle or rod is placed in the hands of the child, who is then brought close to another object, i.e., the child is laid near the wall or near the railing of its bed—or else an object is held near the child—so that it can beat on the wall, the railing, or the object with its rattle.

   Successful reaction: The child beats the still object with the one which it holds in its hands.

6. *Laughing as a General Reaction.* Usually laughing occurs spontaneously during the test; this type of laughing is not to be considered a social reaction. The child laughs at its own movements when touched (tickled, petted) or at a presented object. The examiner can attempt to provoke this reaction in case it does not occur spontaneously.

   Successful reaction: Smiling or laughing in response to any stimulus other than the face and voice of a person.

7. *Napkin Experiment—Lying Face Down.* The child is placed face down on a horizontal surface (II-2).

A napkin is placed over its head, and the edges which hang down over his forehead are pulled backwards over the shoulders, so that the napkin covers the child's face.

Successful reaction: The child frees itself from the napkin by taking hold of it with its hands.

8. *Removing Toys.* Procedure same as in V-5.

   Successful reaction. Same as in V-5. Duration of reaction, 40 seconds.

9. *Actively Seeking Contact.* The examiner stands next to the bed and pays no attention to the child and avoids looking at the face of the child.

   Successful reaction: Efforts of the child to effect a contact; babbling, seeking the eye of the examiner.

10. *Imitating Sounds.* The examiner bends down over the child and repeats several times a long drawn-out, loud, gutteral "re."

    Successful reaction: Every effort of the child to make a sound which even slightly approximates that produced by the examiner. The reaction can occur during or after the test.

VII. SEVEN-MONTHS TEST

1. *Pushing away Source of Stimulation.* Procedure same as in II-6 and III-6.

   Successful reaction: The child reaches for the hand of the examiner and removes it from its face.

2. *Locomotion.* The reaction here desired cannot be a provoked reaction at all, the latter will occur during the half hour that the examiner spends with the child.

   Successful reaction: The child turns from its back to the side, from the side to the stomach, then to the other side, and then to its back again; or it may move in any fashion, sideways, from where it has been before.

3. *Striving after a Desired Object by Locomotion.* A rattle, or if this does not sufficiently engage the interest of the child, a rubber or stuffed animal is brought near the child and left in such a position that it can see the object but cannot reach it. One

can place the object on the pillow near the child or can leave it in the line of regard; the child can reach the object only by lifting head and shoulders or by some other change in position.

Successful reaction: Besides reaching, the child makes some other movement towards the object.

4. *Manipulating Two Objects.* The child that is occupied with a rattle, which it is holding in its hands, is offered a second rattle.

   Successful reaction: The child holds both objects simultaneously and moves them.

5. *Imitating Knocking.* The examiner knocks with rattle against railing of the bed near the child.

   Successful reaction: Every movement of the child which is similar to that demonstrated with the rattle by the adult.

6. *Removing Toys.* Procedure same as in IV-8.

   Successful reaction: The child follows the toy with his eyes and turns his head, searchingly, for at least 52 seconds.

7. *Paper Test.* A piece of white writing paper (15 cm. x 20 cm.) is placed in the child's hands.

   Successful reaction: The paper is crumpled, compressed, torn; its form is in some way changed.

8. *Napkin Test—Sitting with Support.* The child, who is in the position described in VI-1, has a napkin placed over its head.

   Successful reaction: The child removes the napkin with its hands without falling over.

9. *Differentiating between Friendly and Angry Facial Expression.* The adult bends down over the child and smiles at it for a time; then he changes his expression, his forehead becomes creased, and he looks at the child angrily.

   Successful reaction: Positive reaction to the friendly countenance; negative reaction to the angry expression. The problem is considered solved only if *more* expressive movements occur than merely those demonstrated by the adult.

10. *Taking Toys away from the Adult.* The adult quietly lays his hand, which holds a rattle, within reaching distance of the child, on the bed.

Successful reaction: The child displays some effort and strength in trying to take the toy away from the adult.

VIII. EIGHT-MONTHS TEST

1. *Sitting without Support.* The child is seated without any support in the middle of the bed.

Successful reaction: The child remains sitting upright.

2. *Memory Reaction.* Procedure same as in IV-8.

Successful reaction: Gazing after (the person) (at least 60 seconds).

3. *Crawling.* This reaction also usually occurs during the course of the test, without the introduction of a special stimulus.

Successful reaction: The child crawls forward or backward. If it only rolls sidewise, the problem is not considered solved.

4. *Purposive Selection of a Toy.* The examiner holds two different toys, a rattle and a rubber animal, one in each hand, within reaching distance of the child, and waits until the child has seized one of them. Then the seized toy is taken away from the child; the examiner again holds the two toys towards the child in the same way as before, except that the object which was formerly in the right hand is now in the left, and vice versa.

Successful reaction: When offered the two toys a second time, the child takes the same one as he took the first time.

5. *Mirror Experiment.* A hand mirror (15 cm. x 20 cm.) is held before the child at a distance of 1/4 meter.

Successful reaction: The child smiles (laughs) at his reflection or else observes it with interest.

6. *Reaction to a Strange Environment.* The child is brought into an unfamiliar room, or else his usual

environment is changed by hanging (draping) a dark cloth over his bed, leaving only a small slit open through which the child can be observed.

Successful reaction: Negative expressive movements; at least a weak negative surprise.

7. *Imitating the Squeezing of a Doll.* Before the eyes of the child the examiner several times squeezes a squeaking doll or rubber, pressing hard enough to cause the doll to make its characteristic sound. Then he hands the doll over to the child.

   Successful reaction: Every attempt of the child to imitate the movements demonstrated by the adult.

8. *Preferring Paper to Other Toys.* A piece of paper (VIII-4) is handed to the child while it is engaged with some other toy. After the child has busied itself with the paper, the latter is again replaced by the original toy, and then the paper is offered a second time.

   Successful reaction: The child at once abandons the toy and attends exclusively to the paper.

9. *Removing Toys.* Procedure same as in IV-8.

   Successful reaction: Looking for the toy. (Duration of reaction 68 seconds.) The test is considered solved only if there is a definite negative affective reaction, such as is characteristic of the eight-months-old child.

10. *Striving for an Object outside of the Bed.* A toy is held outside of the bed but in the plane of the upper surface of the bed; if a chair whose seat is even with the plane of the bed is available, the toy can be placed on this chair.

    Successful reaction: The child reaches through the railing of the bed and takes the toy.

IX. Nine-Months Test

1. *Kneeling with Support.* The examiner gets the child into a kneeling position, supporting it in the small of the back and at the lower margin of the thorax (lower ribs).

   Successful reaction: The child remains in this position.

2. *Understanding Gestures.* The examiner steps before the child, and, when the latter looks at him, raises his hand in a threatening position; he repeats this threatening gesture for 30 seconds. After a little pause, he stretches his hands demandingly towards the child, and through various movements entices the child to come toward him. In all this the face remains unchanged and as expressionless as possible.

   Successful reaction: Negative reaction, negative expressive movements, and bending away in response to the threatening gesture. Positive reaction, positive expressive movements, smiling, bending towards the examiner, in response to the alluring, seductive gesture.

3. *Pocket Experiment.* Before the eyes of the child a toy is put into the overcoat pocket of the examiner; the pocket is then brought near the bed so that with a little movement the child can reach into it.

   Successful reaction: The child takes the toy out of the pocket.

4. *Destructive Activity.* A tower is built up before the sitting child, by placing hollow blocks on top of each other. We used, for this purpose, six hollow blocks with one of the six sides absent, so that the blocks could be fitted into one another. The six cubes measure 4, 6, 8, 10, 12, and 14 cm. along a side, respectively.

   Successful reaction: The child tries to destroy the tower.

5. *Imitating the Opening and Closing of a Picture-Book.* Before the eyes of the child, the examiner several times opens and closes a picture-book, and then places the book (20 cm. x 12 cm.) into the hands of the child.

   Successful reaction: Any attempt of the child to imitate the demonstrated movements with the picture-book.

6. *Memory Experiment.* Procedure same as in VIII-2.

   Successful reaction: Duration of reaction, 70 seconds.

7. *Attracting Attention of the Adult.* The examiner stands next to the child, turns his back to the child, and is apparently interested in something else.

   Successful reaction: Attempts of the child to gain the interest of the adult by pulling at his clothing, handing him toys, or making sounds directed towards the examiner.

8. *Grasping Two Objects while Sitting without Support.* First one and then a second toy (rattle and rubber doll) are handed to the child who is sitting without support.

   Successful reaction: The child reaches for the second object without dropping the first one, and without losing his sitting posture.

9. *Peek-a-boo Game.* The examiner stands at a distance of 1/2 meter before the child and covers his face with a napkin; after 10 seconds he removes the napkin and 10 seconds later puts it over his face again; when he has the napkin over his face he says, "Where's the baby?" and when he removes it, says, "There he is!"

   Successful reaction: The child looks in the direction of the examiner's face, is interested, and greets his appearance with laughter.

10. *Adaptation (Habituation) to the Unfamiliar Adult.*

    Successful reaction: The child, who at first regarded the adult with some fear, perhaps even crying, changes its attitude during the course of the test, smiling at the adult or at least not being stimulated to displeasure by him.

X. TEN-MONTHS TEST

1. *Imitating the Sounding of a Bell.* The examiner demonstrates before the child the sounding of a bell by swinging it back and forth and then turns the bell over to the child.

   Successful reaction: Any attempt of the child to imitate the demonstrated movements.

2. *Napkin Test—Sitting without Support.* The child is sitting without support; a napkin is placed over its head in the same way as in VI-7.

Successful reaction: The child frees itself from the napkin without falling over.

3. *Uncovering Hidden Object.* Before the eyes of the child a toy is covered over with a cloth.

   Successful reaction: The child uncovers the object and grasps it.

4. *Glass-Plate Test.* A plate of glass, 1/2 meter long and 30 cm. wide, is placed before the child. In back of the glass a toy is laid; the attention of the child is attracted to the toy.

   Successful reaction: The child reaches to one side of the glass and takes the toy.

5. *Turning in Surprise to the Adult.* The examiner blows a shrill whistle unexpectedly or lights an electric pocket lamp (flash light) near the child.

   Successful reaction: The child looks at the adult questioningly.

6. *Standing with Support.* The child is placed on its feet in such a way that it can hold on to the railing of its bed, to the top edge of its little stall or to a chair, with its hands.

   Successful reaction: The child can remain standing with support.

7. *Memory Experiment.* A box containing a ball is handed to the child and is left with the child for five minutes. Then the box is taken away, and after 30 seconds is given back, minus the contained ball.

   Successful reaction: The child looks for the toy and then looks at the adult in surprise.

8. *Organized Game with an Adult.* The examiner hands the child a toy, takes it back, gives it again, takes it back, etc. Every time he takes the ball from the child he says "Thank you."

   Successful reaction: The child gives back the object voluntarily and takes it again, in other words, it enters into the game.

9. *Throwing Objects.* The reaction cannot be attained experimentally, but usually occurs spontaneously during the tests.

Successful reaction: The child does not merely let an object fall, but lifts it slightly and then hurls or tosses it away.

10. *Opening Box.* A cardboard box (15 cm. x 10 cm. x 6 cm.) with a very loosely fitting cover (15½ x 10½ x 2) is given to the child, cover on.
Successful reaction: The child opens the box.

XI. Eleven-Months Test

1. *Rising to a Sitting Posture.* An object is handed towards the child in such a way that it cannot reach it from its lying posture.
Successful reaction: The child rises up to a sitting posture.
2. *Retrieving Objects by Means of an Attached String.* A string is tied to a rattle or bell and the toy is then placed beyond the reach of the child. The other end of the string is placed near the child, or, if necessary, in the hands of the child.
Successful reaction: The child pulls the object to itself by the string.
3. *Memory Experiment.* (X-7) The empty box is given back to the child after a wait of one minute.
Successful reaction: The child notices that the ball is missing.
4. *Fitting Blocks into Each Other.* The six hollow blocks (IX-4) are taken apart and are placed before the child.
Successful reaction: The child fits the blocks into each other, placing the smaller ones into the larger ones.
5. *Purposive Placing One Block Aside.*
Successful reaction: In the course of his activity with the blocks, the child sets one block down very carefully, with all signs of attention and purpose of starting a new activity.
6. *Imitating Knocking with a Spoon.* Before the eyes of the child the examiner hits two spoons against each other, and then hands the spoons to the child.

Successful reaction: Attempts of the child to imitate the demonstrated movements.

7. *Imitating Sounds.* The examiner speaks syllables to the child, slowly and plainly, e.g., "mama," "papa," "dada," "lala," etc.

   Successful reaction: Attempts of the child to produce similar sounds.

8. *Fear of the Unfamiliar.* For this test any stimulus which is new to the child can be used; a new toy, an inflatable rubber animal, a strange person, or new situation.

   Successful reaction: Occurrence of negative reactions.

9. *Organized Game with Adult.* The child is sitting up or lying on its back. A napkin is placed over its face, while the examiner says, "Where is the baby?" and when the napkin is removed the examiner says, "There he is!"

   Successful reaction: After several repetitions, the child voluntarily removes the napkin and puts it back over its face.

10. *Opening Box.* (X-10) The cover used in this test fits snugly over the box.

    Successful reaction: The child opens the box.

Method of Administering and Scoring Tests

Since it seems apparent that the maturation or acquisition of a particular type of reaction may normally appear within a range of five months, each subject is presented with all the tests for the two months preceding the chronological age, the ten test items listed at the subject's age level, and all of the tests for the two succeeding months. With the exception of children aged 2, 3, 10, and 11 months, each infant would be presented with 50 different test situations. A child aged 2 or 11 months would be presented with 30 dif-

ferent test situations, and a child aged 3 or 10 months would be presented with 40 different test situations. For example, an infant 6 months of age chronologically would be given all the tests listed at the fourth, fifth, sixth, seventh, and eight months on the scale. A three-months-old infant would be presented with all the test situations listed at the second-, third-, fourth-, and fifth-month levels.

In scoring, complete credit is given for all tests below two months less than the chronological age. That is, the six-months-old infant would be given complete credit for tests listed at the second- and third-month levels on the scale. An infant is rated in terms of success or failure—plus or minus—on all of the items within the range of two months below and two months above the chronological age. No partial credit is allowed. Credit is given only for those situations which are actually achieved during the test situation, except in a few instances where the report of the mother or nurse is accepted.

A value of three days toward a developmental age is assigned to each test successfully passed. This is justified, since there are, for all practical purposes, 30 days to a month, and the scale contains 10 different test situations at each month level. And, since a particular trait may normally appear any time within the range of five months, equal credit for successful tests, irrespective of allocation, seems reasonable. The number of tests successfully passed, when totalled, multiplied by three, and added to the full credit allowed for the months preceding the level at which the testing

began, will yield a developmental age. An index of the infant's development may be obtained by getting the ratio between the infant's chronological age and his developmental age. In other words, DA divided by CA yields DQ. For example, a six-months-old infant who was given all the tests at the four-, five-, six-, seven-, and eight-months levels passed the following:

8 tests at the four-months level
8 tests at the five-months level
7 tests at the sixth-months level
7 tests at the seven-months level
4 tests at the eight-months level

This performance yields a total of 34 tests successfully passed, or 102 days toward his DA. This score of 102, added to the 90 days full credit allowed for the first, second, and third months, makes a total DA of 192. The DA thus obtained divided by his CA of 180 days yields a DQ of 107.

The above method of scoring was devised by the author because the method on which the scale was standardized and which appeared in the original publication of the test seemed statistically unwieldly for a comparative study of this sort. In the English translation of the scale, however, the authors have adopted a scheme of scoring which is not very different from that employed by the writer. They give no norms for their scale based on this new method of scoring, and a comparison between their findings and those of the writer is hardly feasible or justifiable.

Several of the test items were modified as to materials or procedure in this study, but, since no com-

parison is made with the Vienna norms, the matter is irrelevant because such changes were held constant for both groups of infants here studied. However, for the sake of clarity in case this scale should be used for future comparative studies these changes in procedure or materials should be explained.

Test IV-1. Lying Supported on Hand Surfaces. According to standardization the infant should be placed upon his hands, and if he sustains the position for a given length of time the test is passed. Due to a misinterpretation of translation our procedure gave a plus score to the child only if he raised himself up, as well as sustained the position for a few moments.

Test XI-4. Fitting Blocks into Each Other. The translation seems to indicate the placing of six blocks together by the child for a successful reaction to this test. In no instance did we find an eleven-months-old baby capable of doing this. Our procedure gave the child a plus rating if he placed *one* block inside another.

Test XI-5. Purposive Placing of One Block Aside. Again due to faulty translation, the writer interpreted this test situation to involve the placing of one or more blocks on top of each other, whereas in fact it seems an early test of initiative.

Tests IX-4, XI-4, XI-5. The blocks used in these tests in the present experiment were made of tin covered with enamel, so that they might be subjected to sterilization processes without warping. They proved to be larger and heavier than the blocks on which the test was standardized.

Test III-9. The mask used in this experiment was a large "head mask" of a pig, whereas the mask used in standardization was a face mask.

Other materials seem to conform very well to those on which the tests were standardized.

There are, in the opinion of the writer, some outstanding frailties in the scale as a means of measuring the development of infants. In some instances the directions are very vague and indefinite. It is possible that a certain degree of clarity and explicitness was lost in translation. For example, at the two-months level it was very difficult to know just what the authors of the scale mean by "experimental movements."

Then some of the situations unfortunately stimulate a negative reaction, as in the Removing Toys Test, which is scored in terms of the time spent in crying for a toy of which the baby has been deprived. Such a test not only stimulates a negative response, but penalizes the baby of resourcefulness. It is quite conceivable that the baby who adjusts to the deprivation of a mere toy and finds contentment in something else, even if it is nothing more than the railing of the bed, or his own fingers, may be a decidedly superior baby. The test offers another difficulty in the subjectivity of scoring. It is not always easy to determine when the baby has ceased crying for the toy and cries for the sheer joy of crying or for some other purpose.

Any test of young infants scored on the basis of time is to that extent unsatisfactory. It was found difficult with the babies in this investigation to sustain interest in the play activity with a ball and a box for five minutes.

In several of the test situations the characteristic reaction, as reported by the authors of the scale, was difficult to stimulate. The Mask Experiment usually brought forth a widening of the eyes, a curious expression, but not "fear." The older babies would usually reach out to touch it. Holding Head and Shoulders Up When Lying on Back was attained from only 14 of the 71 babies to whom the stimulus was presented. Most of the imitative tests were difficult to stimulate and most of them extremely subjective in scoring.

Some of the tests were too easy to be discriminative, as Kneeling with Support, which was achieved by 65 of the 73 babies to whom it was presented. Many of these tests are extremely subjective in rating. This is an element which cannot be entirely eliminated in the measurement of infants, especially if the traits to be measured are to involve anything more than very overt motor muscular reactions and coordinations. The subjectivity of scoring might be considerably curtailed in this particular scale by a refining of the testing technique. Practically all of the imitative tests are noticeably subjective and the imitation or mimicry at the third and fourth months are, in the opinion of the writer, so subjective as to be relatively worthless.

There is, also, in some test situations a possibility of chance success, as in the removing of the diaper by the four-months-old baby when it is thrown over his face. The element of chance may be reduced by extending the edge of the diaper well over the baby's head. (It is doubtful if the element of chance success of these tests if rightly managed is any greater, if as

great, as it is in many of the standardized tests of older children, for example, the Ferguson Form Boards.)

Some of the test items on this scale appear to be quite diagnostic and of a trait not prominent in other standardized tests of young infants. They seem to involve a "grasping" of the total situation. Since the writer is taking up a more critical evaluation of the scale elsewhere, these items will simply be mentioned here. They are tests such as The Glass-Plate Test, Organized Game with an Adult, Uncovering a Hidden Object, Pocket Experiment, Peek-a-boo, and Retrieving an Object by an Attached String. Carefully Placing a Block Aside seems to be a test of the early appearance of initiative.

Since the completion of the experiment by the writer wherein the above translation of the scale of baby tests was used as the instrument of measurement, an English translation has appeared in the book by Dr. Charlotte Bühler called the *First Year of Life*. This translation was made by Rowena Ripin and has the approval of Dr. Bühler and the authors of the scale. Critical analysis reveals that the translation used by the writer is in every essential the same as that sanctioned by the author of this scale except for the introduction of several new test situations and the elimination of other test situations. In the main, these changes are the substitution of a new test situation for Removing Toys, which appears in the original scale from the fourth-month series to the eighth-month series, and the substitution of new test situations for the Memory Experiment, which appears in both the eighth- and ninth-month series. To be specific, these changes are as follows:

Three-Months Test: Reaction to Disappearance of Human Face is substituted for Reaction to Disappearance of Seen Object.

Four-Months Test: Positive Reaction to Light is substituted for Removing Toys.

Five-Months Test: The test items are the same, but the directions for the Removing Toys involve no time limit.

Six-Months Test: Expectation in Response to Repetition of a Stimulus is substituted for Removing Toys.

Seven-Months Test: Loss of Interest in a Repeated Stimulus is substituted for Removing Toys.

Eight-Months Test: Neutral Reaction to Single Stimulus is substituted for Memory Experiment. Persisting Reaction to Withdrawal of a Toy is a modification of the Removing Toys Test in that no time limit is involved in the latter.

Nine-Months Test: Curiosity for That Which is Hidden is substituted for Memory Experiment.

Although the test items in this scale were used by the writer as experimental situations, and the reliability of the scale as a whole is therefore not an issue of paramount importance, a second examination was made upon 16 white babies and 18 colored babies after a lapse of one month from the time of the original examination. The difference in the DQ attained at the first and at the second examination on these 34 babies varied from 0 to 20. The average difference and the modal difference were in both instances 9. There were, on the whole, 30 test situations presented to each of these 34 infants on two different occasions. A com-

parison of their successful responses to the same situation reveals that very seldom did an infant fail a test at the second examination which he had passed at the time of the first examination. This fact seems to indicate that the testing of the infants was not restricted to capricious or mere chance reactions.

Physical Measurements

In addition to the developmental index obtained by means of the above scale, the following gross physical measurements were taken of each baby (*a*) body length; (*b*) body weight; and (*c*) stem length. For all measurements the baby was freed of all clothing. Body and stem length were taken by laying the infant on his back upon a hard table surface covered only with rubber and muslin sheeting. Two right-angle boards were constructed so that they would rest on the table, but would be easily movable. One was placed at the infant's head and the other at his heels or rump while the legs and body were extended and lying flat on the table surface. The distance was then measured from the head-board to the foot-board by a steel tape. A standard baby scale was used for taking weight. To reduce the error of measurement each measurement was made three times, and the mid-point between the two closest measurements was the accepted one.

Summary

This chapter gives a detailed description of the particular test items in the Hetzer and Wolf scale of "Baby Tests," directions for administration and scor-

ing as adapted in the present investigation, a qualitative evaluation of some of the test items, and a description of the method used in taking gross anthropometric measures on the babies in this experiment.

IV

QUANTITATIVE RESULTS

The comparative developmental achievement of white and Negro infants as measured by the Vienna scale of "Baby Tests," expressed in terms of developmental quotient, is revealed by the following data. First, as the accompanying graphs well illustrate the DQ's of both groups follow a normal distribution curve, with approximately the same variability. Developmental quotients of the colored group ranged from 53 to 123, and those of the whites from 68 to 142. Moreover, there is, notwithstanding the modicum of cases at a given age, a variability of DQ's at each month level, which is suggestive of the discriminative value of the scale at any particular age. The lowest and highest DQ's of the Negro group fell to the three-months-old babies. A seven-months-old baby achieved the highest DQ among the white group, and a five-months-old baby rated the lowest. The lowest range of DQ's for any particular group was the four-months-old Negro babies, but this would seem to be a matter of chance and not *ipso facto* indicative of an inadequacy of the tests at that level since the DQ's of the four-months-old white babies ranged from 75 to 140. The average DQ's at each age level for both groups are shown in Table 2.

It will be noticed that, with the exception of the three-months-old Negro babies, there is a tendency for the higher DQ's to fall at the first three months of the scale, that is, before the infants are five months old.

TABLE 2

TABLE SHOWING AVERAGE DQ ACHIEVED BY WHITE AND NEGRO INFANTS AT EACH AGE LEVEL

Age (months)	No. of cases Male	Female	Total	Mean DQ	Range
		White			
2	2	5	7	120	100-140
3	2	5	7	113	93-140
4	0	4	4	111	73-140
5	3	6	9	99	68-116
6	3	3	6	99	81- 99
7	3	5	8	108	88-142
8	5	6	11	104	84-137
9	3	2	5	95	90-102
10	4	2	6	99	92-110
11	3	2	5	89	82- 95
		Negro			
2	2	1	3	100	65-120
3	4	1	5	88	53-123
4	2	2	4	106	102-110
5	4	1	5	94	72-112
6	4	7	11	97	75-116
7	3	1	4	92	54-110
8	5	3	8	93	82-107
9	2	7	9	90	61- 99
10	3	3	6	83	71- 93
11	2	3	5	85	64- 92

This may be an artifact inherent in the scoring of the test, or it may be that truly discriminative traits do not culminate in the life of a child until about the fourth month. Whatever the explanation of this tendency for higher DQ's to appear at the lower end of the scale, it will be noticed, however, that in terms of DQ's the difference in the achievement of white and colored infants is as great or greater here than it is at the upper age levels. The lower average DQ's for the ten- and eleven-months-old infants is indubitably an artifact. Since the scale terminated with the eleven-month tests the maximum rating of ten- and eleven-months-old infants was, of course, not obtained.

It will be observed that the subjects are fairly well distributed as to sex in both the white and Negro groups. The average DQ for the white girls was 105. The average DQ for the white boys was 103. The average DQ for the Negro girls was 92, and the average DQ for the Negro boys was 91. The frequency distribution, when divided as to the sexes, yields figures too small for statistical treatment, but these average DQ's seem to suggest that sex is a negligible factor in this investigation.

The mean DQ of the total number of white infants (68) was 105, S.D. 17, and that of the total group of Negroes (60) was 92, S.D. 16. The differences in these means is slightly more than four times the standard error of the difference—to be exact 4.04. This is a statistically reliable difference, evidencing a true difference between these two groups of infants, or a difference greater than would be realized by chance alone. This difference is in favor of the whites. Although the means suggests an evident superiority of the white babies, there is considerable overlapping in the distribution of DQ's of the two groups. For example, the mean score of the white group (105) is equalled or exceeded by 28% of the Negroes, whereas the mean DQ (92) of the Negro group is equalled or exceeded by 71% of the whites. The relative amount of overlapping can be visualized from the graphs in Figure 1.

A more accurate comparison of the performance of the two groups as measured in a test situation can be realized in terms of the percentage of successful reactions elicited from each group of infants. It will be

recalled from the preceding chapter that there is a total of one hundred different test situations in the scale. Each infant aged two and eleven months was rated upon 30 of these test items; infants aged three and ten months were rated upon 40 different test items; and all other infants were rated upon 50 test situations. The comparison is expressed in terms of the percentage of successes achieved by the two groups at each age level as shown in Table 3.

The same differences are well illustrated graphically in Figure 2.

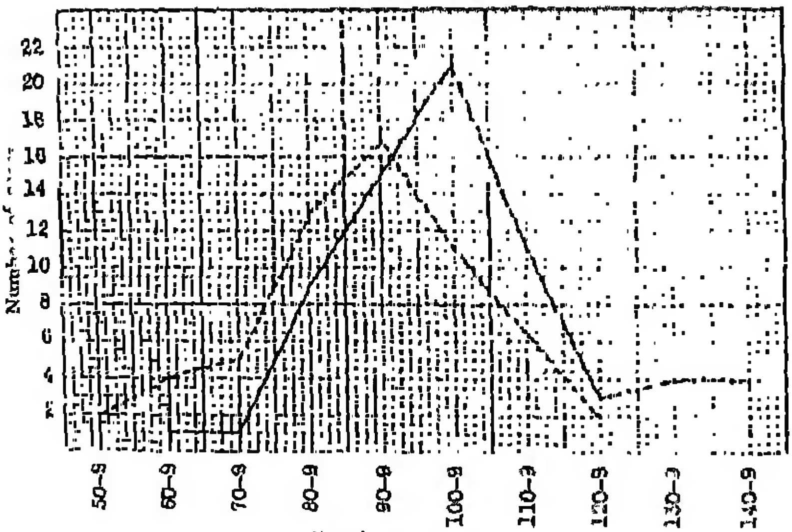

FIGURE 1

Distribution of Developmental Quotients for White and Negro Infants

White—solid line
Negro—dotted line

TABLE 3
PERCENTAGE OF SUCCESSES FROM TOTAL NUMBER OF TEST SITUATIONS PRESENTED

Age (months)	White	Colored
2	51	39
3	59	47
4	58	60
5	60	45
6	57	55
7	62	53
8	65	48
9	56	42
10	56	44
11	70	44

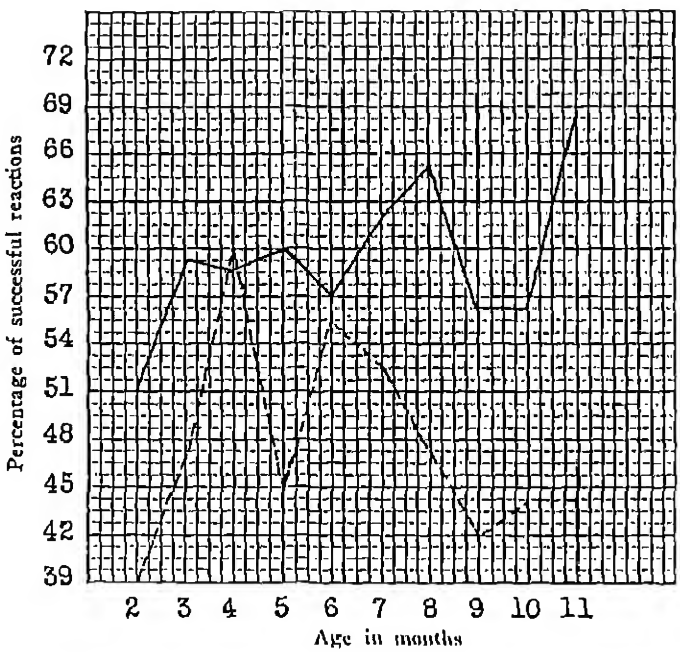

FIGURE 2
PERCENTAGE OF SUCCESSFUL REACTIONS ACHIEVED BY WHITE AND NEGRO INFANTS AT THE DIFFERENT AGE LEVELS
White—solid line
Negro—dotted line

These percentage differences expressed in terms of the sigma of the difference

$$\left(\frac{Diff._p}{\sigma_{diff.}} \right)^1$$

are given in Table 4.

TABLE 4
RELIABILITIES OF DIFFERENCES BETWEEN PERCENTAGES OF SUCCESS OF WHITE AND COLORED INFANTS

Age (months)	$\frac{Diff.}{\sigma_{p\ diff.}}$	Chances in 100 of a difference greater than zero in favor of whites
2	1.90	97
3	2.60	99
4	—0.15	43
5	4.85	100
6	0.64	74
7	2.15	98
8	5.27	100
9	3.65	100
10	4.25	100
11	4.65	100

With the exception of the four-months-old babies, there is, in every instance, a difference in favor of the superiority of the whites when considering the percentage of successful reactions to the various test situations

[1]The sigma of the percentage and the sigma of the percentage difference were computed by the following formulae:

$$\sigma_p = \sqrt{\frac{p \times q}{n}}$$

where p = the percentage of success, q = the percentage of failure, and n = the number of cases.

$$\sigma_{p\ diff.} = \sqrt{\sigma_{p\,w}^2 + \sigma_{p\,c}^2}$$

where w represents the white and c the colored.

presented to the infants. This slight difference in favor of the Negro babies at the fourth-month level is statistically insignificant and appears to be due to chance. There were only four babies among the Negro group at this age, and, as mentioned, this group shows the least variation in terms of DQ of all the other age groups, white or colored. Moreover, the average DQ of this particular group of colored babies is the highest group average achieved by the Negro infants.

It is evident from the above table that the differences at five, eight, nine, ten, and eleven months are statistically significant, indicating a reliable superiority of these white infants to the particular group of colored infants studied at the same age level. It is noticeable that there is a tendency for the differences in successes and failures to become increasingly significant at the upper end of the scale. This is interesting in view of the fact that at the upper end of the scale the tests become more purposive, selective, and discriminative. They involve more situations requiring the sustaining of attention, purpose, and effort toward the achieving of a definite goal, and an understanding of a means whereby the objective may be obtained.

An analysis was also made in terms of the percentage of children failing or passing each particular test item, in order to determine if there were any consistencies in the type of tests passed or failed by either group. The following test items were passed by a larger percentage of the Negro babies than of the white babies, but in no instance was the percentage difference statistically significant:

II-1	Holding Head Erect
II-7	Social Reactions
II-10	Experimental Movements
III-9	Experiment with Mask
III-10	Imitating Mimicry
IV-1	Lying Supported only on Hand Surfaces
IV-2	Reaching for a Touched Object
IV-3	Grasping with Both Hands without Using Fingers
IV-4	Handling and Moving About an Object
IV-5	Looking at a Touched Object
IV-8	Adult Playmate Leaves the Child
V-4	Differentiating between Friendly and Angry Expression of a Person
V-9	Positive Reaction to Clangs
V-10	Imitating Mimicry
VI-5	Manipulating a Still Object with a Moving One
VI-9	Actively Seeking Contact
VI-10	Imitating Sounds
VII-8	Napkin Test—Sitting with Support
VIII-1	Sitting without Support
XI-8	Fear of the Unfamiliar

Although these differences are statistically unreliable, and could therefore be explained in terms of chance alone, a tentative analysis or classification of the test items may be of value since there are only 20 situations out of a possible 100 on which the colored infants showed a larger percentage of successes. It will also be noted that 6 of these 20 test situations fell in the fourth-month level, and an explanation has already been made for the fact that the four-months-old Negro babies made a slightly superior rating to that of the white babies in terms of successful reactions to the tests presented to them. The test items showing the greatest difference in favor of the Negroes were:

(*a*) Fear of the Unfamiliar; (*b*) Imitating Mimicry; (*c*) Manipulating a Still Object with a Moving One; and (*d*) Grasping with Both Hands without Using the Fingers. While there is much overlapping, of course, in characterizing the type of reactions involved in these 20 test situations, in at least seven of them the social element, that is, the interplay between the examiner and the infant, seems to be paramount; seven involve largely the baby's interest, reaction to and defense against materials; three are almost entirely tests of body control; the successful response to two of these situations involves a reaction of fear, and one, Experimental Movements, is beyond classification by the writer, since the purpose and administration of the test was not well understood.

In contrast, the white babies show a statistically reliable superiority in the following test situations:

II-4	Taking Fright at Loud Sound Stimulus
IX-4	Destructive Activity
X-3	Uncovering Hidden Object
X-4	Glass-Plate Test
X-5	Turning in Surprise to the Adult
XI-6	Imitating Knocks with a Spoon

There are two plausible explanations for the superiority of the white babies on the first items here mentioned. This response is well recognized as primarily a reflex action, and it is conceivable that the colored babies coming from large and less organized families become inured or adapted to loud noises sooner, and the response is therefore more readily elicited from the better protected babies at the age of two months. Another possible explanation is a statistical one. Of

the 19 white babies rated on this test 7 (37%) were only two months of age, and of the 13 colored babies rated on this particular test only 3 (23%) were two months old. Older infants have presumably matured beyond the period of primary reflex reactions to this type of stimulus.

The destructive title to the contrary, Test IX-4 seems to involve an early gleam of curiosity and spontaneity of reaction. Purposive knocking down a tower of blocks appears to be for the infant investigatory, and indicative of a stage of maturation relatively complex in nature.

Uncovering a Hidden Object and the Glass-Plate Test are, in the opinion of the writer, two of the most diagnostic tests in the whole series—they involve not only perceiving the objective, but the means whereby it is attained.

Other test items on which the white babies show some superiority over the colored babies, though the difference is of variable significance, are in the order of their difference in terms of the sigma of the difference, as follows:

VIII-4	Purposive Selection of a Toy
VII-2	Locomotion
IX-5	Imitating the Opening and Closing of a Picture-Book
VII-7	Paper Test
X-7	Memory Experiment
V-7	Defense When Toys Are Taken Away
III-5	Reaction to Disappearance of a Seen Object
V-6	Removing Toys
VII-10	Taking Toys Away from an Adult
III-6	Changed Reaction upon Repeated Stimulation
VI-3	Displeasure after Vain Grasping

IX-10	Adaptation to the Unfamiliar Adult
VI-6	Laughing as a General Reaction
XI-7	Imitating Sounds
X-9	Throwing Objects
XI-9	Organized Game with an Adult
X-1	Imitating the Sounding of a Bell

In all, the white babies showed some superiority in percentage of successes in 76 of the 100 different test situations; on 4 tests the whites and blacks were equal; and, as previously stated, the Negroes made a larger percentage of successful responses to 20 of the 100 test situations. The 4 tests on which an equal percentage of correct responses were made were:

II-5	Fixating
VIII-6	Reaction to Strange Environment
VIII-10	Striving after an Object Outside the Bed
V-5	Napkin Experiment—Lying on Back

Qualitatively, the reactions of the whites and colored babies to the various test situations were surprisingly similar. This was true even in situations where, due either to change in materials or procedure, or to some difference in American and Viennese infants, the characteristic responses of these infants were quite different from those reported of the Vienna babies, as for example, the experiment with the mask.

Physical Differences

The comparison of the height and weight of the two groups of infants examined not only with each other, but with their respective norms or standards is well shown in Figures 3-6. It is easily perceived that the white babies (with the single exception of the height

of the two-months-old white boys)—both boys and girls—are consistently above the Negro babies in both height and weight. This is also true of the standards for the two groups. The weight of the white girls in this investigation is much in advance not only of Negro girls, but of the norms for white girls throughout the country. The standard heights and weights here quoted were taken from U. S. Publication Bulletin No. 87, and an explanation of the basis on which they were compiled is significant in the light of these comparisons. "A comparatively small number of records, 4,976, of Negro children were tabulated. Of these 224 were weighed and measured in New England and and Middle Atlantic States, 2,567, in the Southern States; 564 in the North-Central group of States; 217 in Iowa, 106 in the Western group, and 126 in California. . . . . (and) 1,172 who were weighed and measured in New York City (in underclothing) were included to make a group large enough to be tabulated. . . . . the inclusion of these children weighed in underclothing tends to understate the difference between the averages of the white and the Negro children. . . . . .The average deficiency of the Negro in stature is about two-fifths of an inch, or 1.3 percent, for boys and one-fifth of an inch or 0.08 percent for girls. In weight the average deficiency is nearly 11 ounces for boys and 9 ounces for girls, 3 percent and 2.5 percent respectively" (118).

Tables 5 and 6 show the height and weight of the infants in this investigation and their variation from their respective norms.

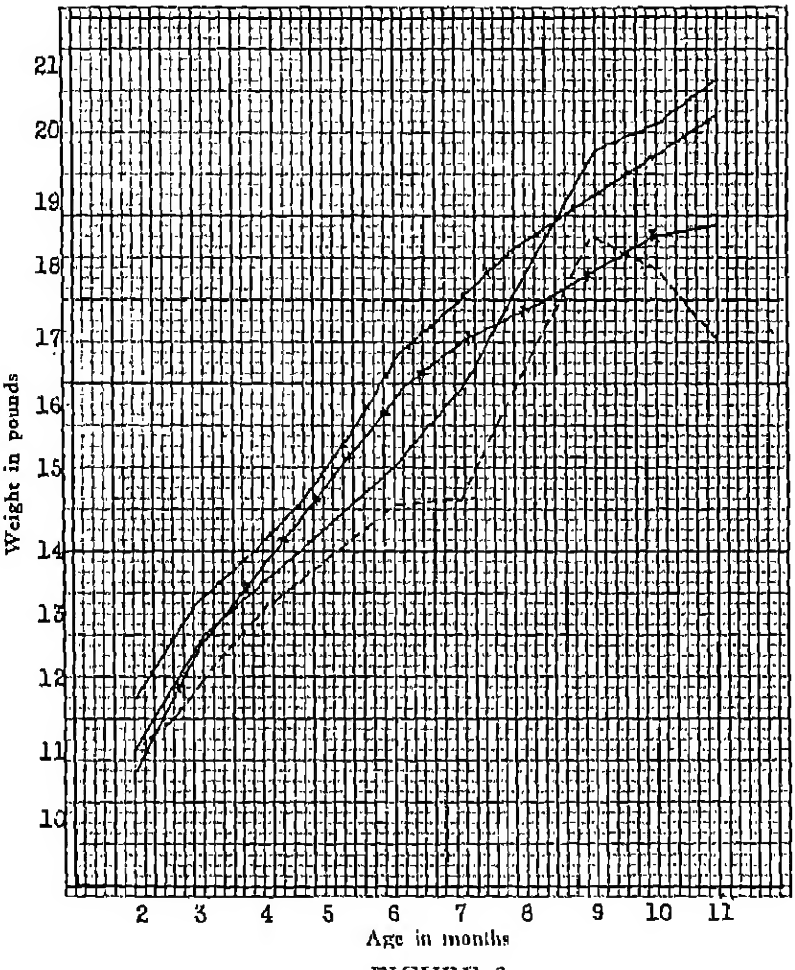

FIGURE 3

STANDARD WEIGHT OF WHITE AND NEGRO BOYS AND WEIGHT OF EXPERIMENTAL WHITE AND NEGRO BOYS AT THE DIFFERENT AGE LEVELS

Standard White -+-+-+-+-+-+-
Experimental White ——————
Standard Negro -x-x-x-x-x-
Experimental Negro - - - - - - - - - - -

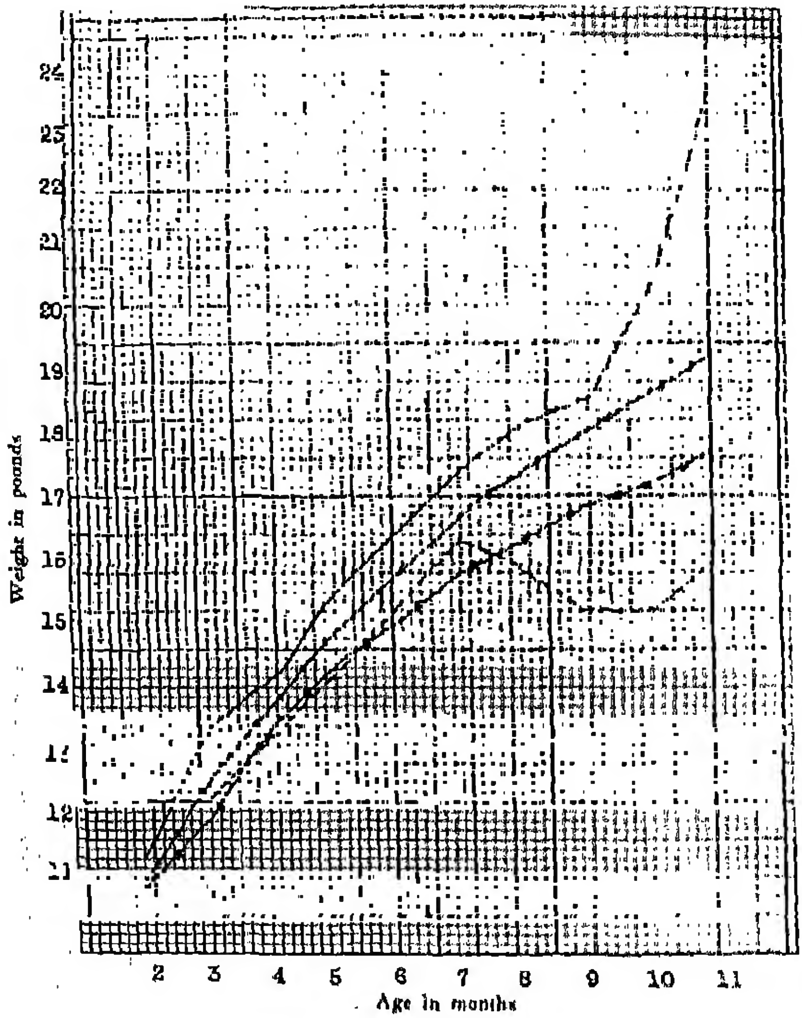

FIGURE 4

STANDARD WEIGHT OF WHITE AND NEGRO GIRLS AND WEIGHT OF EXPERIMENTAL WHITE AND NEGRO GIRLS AT THE DIFFERENT AGE LEVELS

Standard White —+—+—+—+—+—

Experimental White ——————

Standard Negro —x—x—x—x—

Experimental Negro - - - - - - - - - - -

TABLE 5

WEIGHTS OF INFANTS AND THEIR VARIATION FROM NORMS

Age (months)	Weight (pounds)	Norm	Diff.	Weight (pounds)	Norm	Diff.
	WHITE BOYS			NEGRO BOYS		
2	11.00	11.75	—0.75	11.00	10.99	0.01
3	12.75	13.34	—0.69	12.17	12.66	—0.49
4		14.14		13.36	13.97	—0.63
5		15.43		14.00	15.21	—1.21
6	15.13	16.99	—1.86	14.75	16.04	—1.29
7	16.53	17.89	—1.36	14.70	16.72	—2.02
8	18.23	18.68	—0.45	16.82	17.02	0.20
9	19.90	19.36	0.54	18.75	17.62	1.13
10	20.26	19.98	0.28	18.20	18.64	—0.44
11	21.00	20.54	0.46	16.50	18.82	—2.32
	WHITE GIRLS			NEGRO GIRLS		
2	11.20	10.93	0.27	12.00	10.09	0.91
3	13.30	12.37	0.93	12.00	11.76	0.24
4	14.00	13.64	0.36	13.20	13.28	—0.08
5	15.40	14.79	0.61	14.10	14.15	—0.05
6	16.40	15.79	0.61	15.30	15.12	0.18
7	17.40	16.68	0.62	16.40	15.92	0.48
8	18.10	17.45	0.65	15.90	16.31	0.41
9	18.50	18.13	0.37	15.30	16.93	—1.63
10	20.45	18.74	1.71	15.30	17.29	—1.99
11	23.50	19.30	4.20	16.00	17.87	—1.87

It will be noticed that the infants studied, both colored and white, varied very little from their respective norms in height, but that the colored babies, boys and girls, fall noticeably below their norms in weight, and that the divergence from the standard increases with age. Figure 7 illustrates the divergence of both white and colored babies in terms of developmental age, as achieved on the Vienna scale, from the chronological age. It is apparent from this graph that the developmental ages of both the white and colored babies fall below their chronological age at the upper end of the scale. It has already been explained that the low developmental ages at this end of the scale are at-

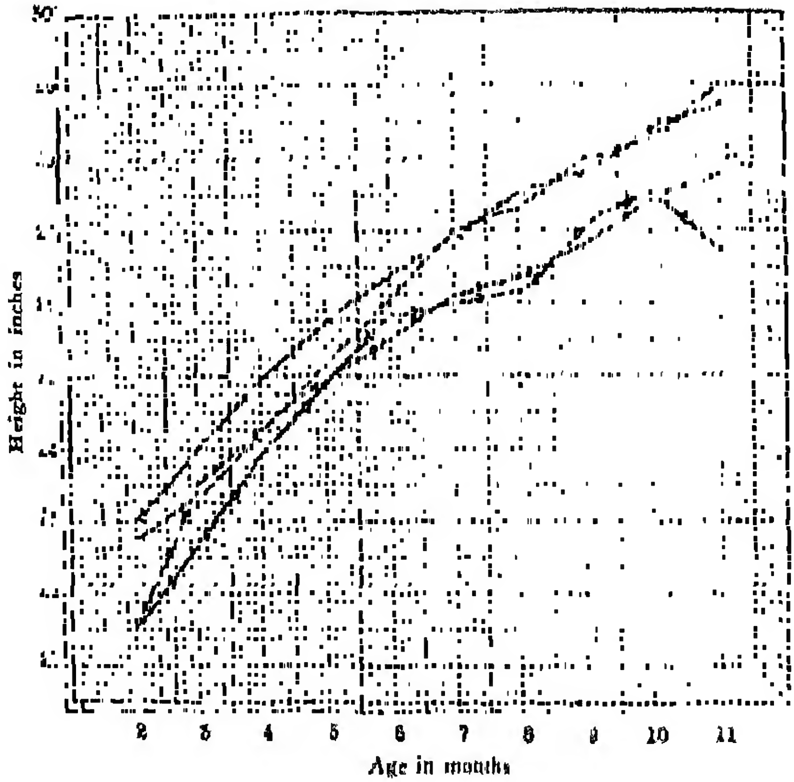

FIGURE 5

STANDARD HEIGHT OF WHITE AND NEGRO BOYS AND HEIGHT OF EXPERIMENTAL WHITE AND NEGRO BOYS AT THE DIFFERENT AGE LEVELS

Standard White
Standard Negro
Experimental Negro
Experimental White

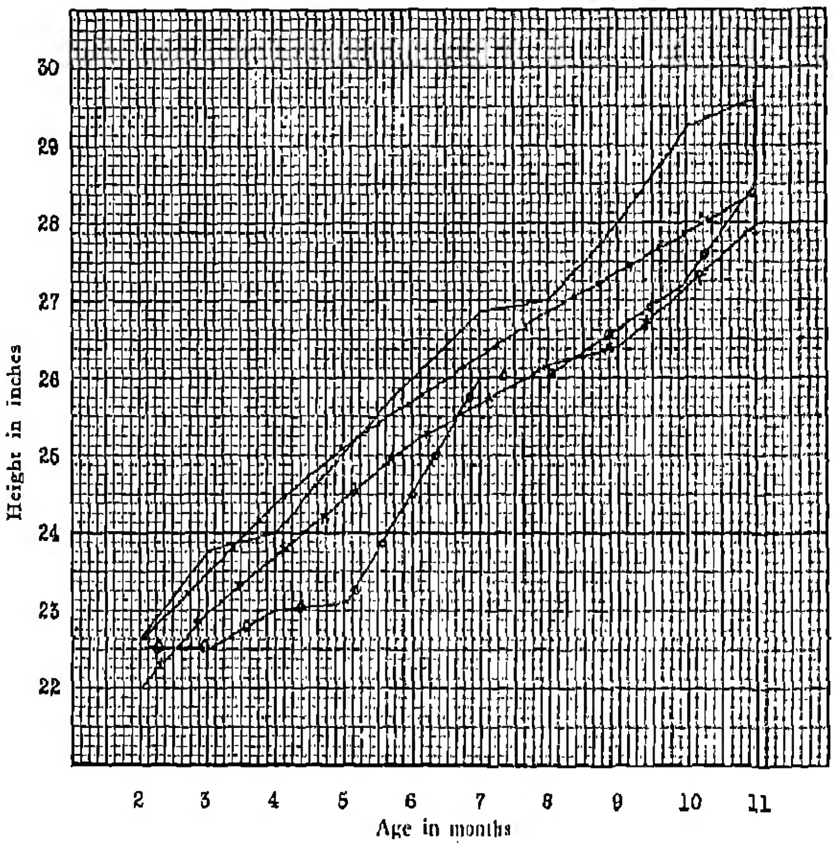

FIGURE 6

STANDARD HEIGHT OF WHITE AND NEGRO GIRLS AND HEIGHT OF EXPERIMENTAL WHITE AND NEGRO GIRLS AT THE DIFFERENT AGE LEVELS

Standard White
Experimental White
Standard Negro
Experimental Negro

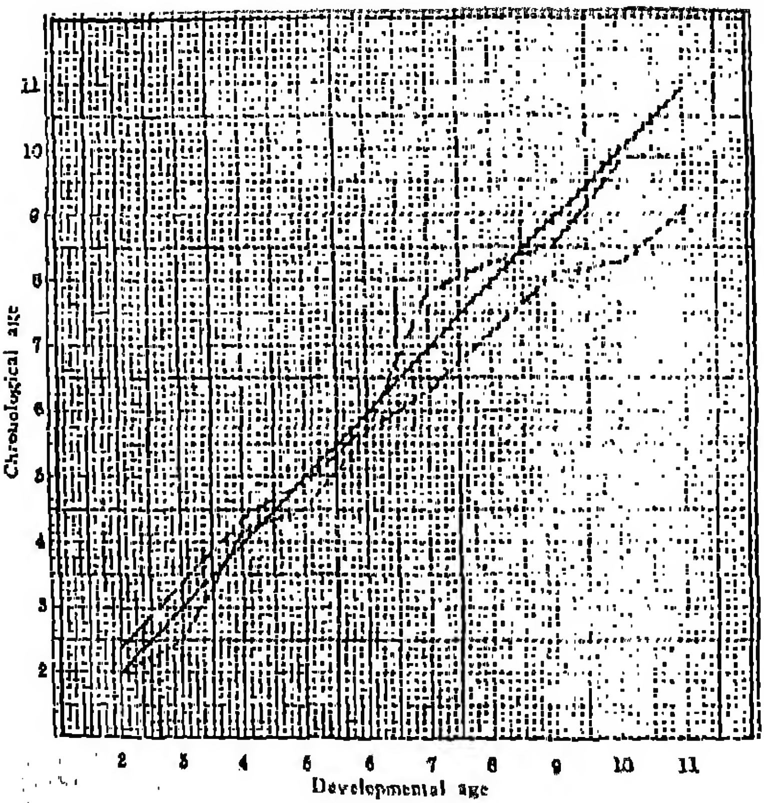

FIGURE 7

DISTRIBUTION OF DEVELOPMENTAL AGES ATTAINED BY EXPERIMENTAL WHITE AND NEGRO INFANTS

White - - - - - - - -
Negro - - - - - - - -

TABLE 6
HEIGHTS OF INFANTS AND THEIR VARIATION FROM NORMS

Age (months)	Height (inches)	Norm	Diff.	Height (inches)	Norm	Diff.
		WHITE BOYS			NEGRO BOYS	
2	21.50	23.03	—1.57	21.50	22.29	—0.79
3	23.55	24.07	—0.42	22.75	23.47	—0.72
4		24.96		24.00	24.41	—0.41
5		25.74		25.00	25.09	—0.09
6	26.00	26.41	—0.41	25.75	25.67	0.08
7	27.00	27.00	0.00	26.00	26.10	—0.10
8	27.33	27.52	—0.19	26.25	26.32	—0.07
9	28.00	27.99	0.01	27.25	26.93	0.32
10	28.33	28.43	—0.10	27.50	27.59	—0.09
11	29.00	28.85	0.15	26.50	27.72	—1.22
		WHITE GIRLS			NEGRO GIRLS	
2	22.60	22.51	0.09	22.50	21.97	0.53
3	23.75	23.55	0.20	22.50	23.02	—0.52
4	24.00	24.42	—0.42	23.00	23.94	—0.94
5	25.16	25.18	—0.02	23.00	24.54	—1.54
6	26.00	25.84	0.16	24.50	25.22	—0.72
7	26.75	26.43	0.33	26.00	25.89	0.11
8	27.00	26.95	0.05	26.00	26.16	—0.16
9	28.00	27.43	0.57	26.60	26.45	0.15
10	29.25	27.88	1.37	27.37	26.84	0.53
11	29.50	28.31	1.19	28.50	27.54	0.96

tributed to the termination of the scale and the inadequate ratings of the infants at this level.

From the accompanying graphs, there might appear on the surface to be a nutritional factor entering in and modifying the performance of the older Negro babies. While it is possible that the nutritional factor may have a detrimental effect upon the performance of these babies, it hardly seems adequate to explain the consistent difference between white and Negro ratings at every age of the scale. Moreover, it should be kept in mind that the norms with which these Negro babies are compared as to height and weight were compiled on very few cases in many instances, and the physical standards of Negro growth

in infancy are not so well established as is the case with the white standards. However, as a tentative check, a comparison was made between the Negro babies *above* weight and the white babies *below* weight, and the average DQ of the Negro babies above weight was found to be considerably below the average DQ of the white babies under weight. Of the total 60 there were 12 colored babies above weight. Their average DQ was 96, or four points above the average DQ of the unselected Negro group. The average DQ of the 18 white babies, from the total of 68, who were below weight was 108, or 3 points above that of the unselected white group. In other words, there is a difference of 13 points in the average DQ of the unselected white and Negro groups in favor of the whites, and a difference of 12 points, still in favor of the whites, between the average DQ of the underweight white babies and the average DQ of the overweight Negro babies.

Summary

This chapter gives a comparison of the white and Negro babies in terms of developmental quotient, developmental age, the percentage of successful reactions to each test situation, as measured on the Vienna scale of "Baby Tests." There is a consistent but slight superiority in favor of the performances of the white babies. A comparative analysis was also made of the specific tests on which the colored and white babies showed either slight or significant differences. An estimate of the physical development as determined by height and weight is revealed in a comparison of these babies with the standards for white and Negro babies, respectively.

V

GENERAL SUMMARY AND CONCLUSIONS

Previous studies concerning racial characteristics of the American Negro, more properly the American amalgam, suggest the following inferences:

1. The American Negro is a product of white and Negro miscegenation and is, therefore, not an adequate subject for unqualified conclusions concerning Negro traits. It is estimated by Herskovits that about 80% of the American Negro population has some white blood in its heritage.

2. Notwithstanding the admixture of blood, there appears to be marked physical homogeneity, denoting group (if not racial) unanimity, which makes the American Negro a distinct type different from the white race with which he is amalgamated and also from the African race from which he is originated.

3. In view of the above considerations, it would seem that, although purely Negro traits may be ascertained through a study of African subjects, such results would have little significance or reliability so far as interpreting the status of the American Negro is concerned. Since a study of racial characteristics in this country presents a practical aspect, viz., adjusting social organizations to meet the requirements of different groups, studies based upon the "social" rather than the "biologically pure Negro" seem justifiable.

4. Results of studies of Negro racial characteristics in America have been clouded by two very serious experimental handicaps: (*a*) the degree of admixture of

white blood, and (*b*) the effect of environmental factors upon the performances of the Negroes. Conflicting and divergent interpretations of quantitative data are the inevitable result.

Although these factors have not been entirely ruled out in any racial study, the preponderance of experimental data seem to predicate a slight but significant superiority of the American white over the American Negro in most of the so-called intellectual traits. The cause and effect relationship of the findings of these investigations is still a matter of speculation. The extent to which these differences may be attributed to determiners within the biological organism having a racial linkage, or the extent to which they are resultant of environmental disadvantages on the part of the Negro remains undetermined, and unqualified conclusions are unwarranted.

Since no single investigation justifies unquestionable generalizations, a better understanding of the Negro is contingent upon an accumulation of data, gathered under varying conditions and with different experimental controls.

Accepting the measurable differences in performance of the average white and Negro adult, some experimenters support the rather popular notion that the Negro, being an inferior race, develops more rapidly in infancy and early childhood, but attains his maximum level of development earlier than the white child.

Modern psychology, on the other hand, tends to attach considerable prognostic value to the appearance of early maturational behavior patterns in infancy as

indicative of latent mental endowment. This is obviously contrary to the hypothesis that inferior races mature more rapidly in early childhood.

A comparative study of infants of the two groups, American whites and American Negroes, gains significance (*a*) in the limitation of environmental effects, and (*b*) as a check on the rate of maturation of the two groups in terms of early developmental patterns.

The reports of several investigations, estimating the effect of environmental factors upon the development of young children, suggest that the age level when there is the least correlation between social status of parents and the mental or developmental rating of the child is during the first year of life.

Interpretation of the Results of the Present Investigation

The results of this investigation lend no support to the theory that Negro babies mature more rapidly than white babies. The extent to which the difference in rate of growth is indicative of intellectual endowment is a matter of speculation. A longitudinal study, comparing the same subjects over a number of years, would offer more conclusive evidence.

In terms of developmental age, developmental quotient, and percentage of successful reactions, the white babies in this experiment are superior to the Negro babies.

In general, the developmental level achieved by the Negro babies appears to be about 80% as mature as that of the white babies.

There is considerable overlapping in the ratings of

the two groups, there being a greater difference between individuals within a group than there is between the means of the two groups examined.

The babies in this investigation, both white and colored, appear to be a representative sampling of the babies of the two races in the community where the study was conducted. On the basis of the tentative report of the Bureau of Vital Statistics, it seems that about 50% of the babies born during the year in the community in each group were subjects in this investigation. Insofar as this particular community is representative of the Southern population, it may be said with reasonable certainty that Southern white babies are superior to and develop more rapidly than Southern Negro babies.

The white babies also evince superiority in terms of height and weight. This is true of white and Negro babies throughout the country. Although the difference in height and weight corresponds to a difference in performance, this does not appear to be a cause and effect relationship since the underweight white babies are superior to the overweight Negro babies.

Considerable overlapping of the two groups is evidenced in this investigation.

The data of this experiment corroborate the findings of previous investigations on older subjects evincing a "slight but consistent superiority" of the white subjects over the Negroes.

It is significant that even with very young subjects when environmental factors are minimized, the same type and approximately the same degree of superiority is evidenced on the part of the white subjects as that found among older groups.

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UNE ÉTUDE COMPARATIVE D'UN GROUPE D'ENFANTS BLANCS ET NÈGRES DU SUD

(Résumé)

Une étude des différences et des traits de race chez les groupes américains blancs et nègres ne permet pas de généralisations non qualifiées à cause de deux grandes difficultés, à savoir, (1) le mélange des deux races comme on le trouve aux Etats-Unis, et (2) les facteurs inégaux du milieu dont il faut toujours se rendre compte même quand les conditions expérimentales sont bien contrôlées. Par conséquent les études de race dans ce pays nous présentent plusiers conclusions différentes. En général les résultats des enquêtes antérieures indiquent une supériorité assez significative des groupes blancs sur les groupes nègres ou mulâtres et quelques expériences ont soutenu l'hypothèse que le nègre américain et les groups de races soi-disant inférieures se développent plus rapidement à la première époque de la vie, c'est-à-dire, pendant la première partie de l'enfance, mais qu'ils atteignent leur développement maximum à un âge beaucoup moins avancé et à un niveau moins élevé.

Dans le but de rendre le moins important possible l'effet des influences du milieu, on a employé comme sujets de cette enquête seulement des enfants âgés de deux à onze mois. On a choisi au hasard soixante enfants nègres et soixante-huit enfants blancs parmi les enfants de Tallahassee, en Floride, et on les a classés par une Echelle de Tests pour les Bébés selon le Développement, faite et standardisée par Hildegard Hetzer et Käthe Wolf à Vienne. On a maintenu constantes pour les deux groupes les méthodes de choisir les sujets et les conditions expérimentales. On a considéré un sujet "nègre" si tout le monde considérait ses parents "nègres", et l'on n'a pas du tout essayé d'évaluer le degré de sang nègre ou blanc hérité par un sujet.

Quand on compare les deux groupes en termes du "Quotient de Développement" (la proportion entre "l'Âge du Développement" et "l'Âge Chronologique"), on trouve une différence petite mais statistiquement constante en faveur du groupe blanc. La distribution des Q.D. pour les deux groupes forment une "courbe normale" d'à peu près la même variabilité. Les Q.D. des 60 enfants nègres ont varié de 53 à 123, et ceux des enfants blancs de 68 à 142. Le Q.D. moyen du groupe blanc a été de 105, S.D.±17, et le Q.D. moyen du groupe nègre a été de 92, S.D.±16. La différence de ces quotients moyens est plus grande d'un peu plus de quatre fois que l'erreur étalon. Le résultat moyen du groupe blanc a été égalé ou dépassé par 28% des nègres et le résultat moyen du groupe nègre a été ou dépassé par 71% des blancs. En termes du pourcentage des réactions réussies aux différentes situations de test, il y a eu une tendance constante en faveur de la supériorité des blancs. Dans cent différentes situations de test les enfants nègres ont fait un plus grand pourcentage de réponses réussies à vingt, les blancs à soixante-seize, et les deux groupes ont été égaux en quatre situations. Une comparaison des bébés blancs n'ayant pas assez de poids et les bébés nègres ayant trop de poids a toujours montré une petite supériorité des blancs, ce qui semble rendre nulle la nutrition imparfaite comme variable pertinent.

Les résultats de cette enquête ne soutiennent pas la théorie que les bébés nègres arrivent à la maturité plus rapidement que les bébés blancs. En général le niveau de développement atteint par les enfants nègres dans cette enquête semble environ 80% aussi mûr que celui des enfants blancs. Il est significant que, même chez des enfants très jeunes, quand on rend le moins im-

portants que possible les facteurs du milieu, le même type de différence et à peu près le même degré en faveur de la supériorité des groupes blancs se montre comme trouvé antérieurement dans l'étude des sujets plus âgés, tels que les enfants de l'âge scolaire ou les adultes.

McGraw

EINE VERGLEICHENDE UNTERSUCHUNG AN EINER GRUPPE BESTEHEND AUS WEISSEN UND NEGERSÄUGLINGEN AUS DEM SÜDEN DER VEREINIGTEN STAATEN

(Referat)

Eine Untersuchung der Rassenunterschiede und Merkmale von weissen und 'schwarzen' Amerikanischen Gruppen eignet sich nicht für unbeschränkte Verallgemeinerungen. Solchen stehen zwei Hauptschwierigkeiten im Wege: namentlich: 1) die Kreuzung der zwei Rassen wie sie in den Vereinigten Staaten stattfindet; und 2) die einzigartigen Einwirkungen der Umgebung, welche nie völlig ausgeschlossen werden können, selbst wenn die experimentellen Bedingungen gut kontrolliert sind. Folglich sind die Ergebnisse der Untersuchungen an Rassen mannigfaltig und divergierend. Im Allgemeinen wird durch die Lieferung früherer Untersuchungen eine einigermassen bedeutsame Überlegenheit der weissen Gruppen den Neger- und Mulattengruppen gegenüber angedeutet, und es ist einigermassen durch Experimente die Hypothese unterstützt worden, dass der Amerikanische Neger, gemeinschaftlich mit den sogenannten 'tieferstehenden' Rassengruppen sich zwar im frühen Lebensalter,—d.h. während der der Kleinkindheit und frühen Kindheit,—rascher entwickelt, den Höhepunkt seiner Entwicklung aber viel früher und auf niedrigerem Niveau erreicht.

In der Absicht, die Einwirkungen der Umgebung auf das kleinste Mass zu reduzieren, wurden die Versuchspersonen in dieser Untersuchung auf Säuglinge im Alter von 2 bis 11 Monaten beschränkt. Man nahm aufs Geratewohl 60 Neger und 68 weisse Säuglinge aus der Säulingbevölkerung der Stadt Tallahassee, Florida, und klassierte sie nach der Entwicklungsskala ('developmental scale') der von Hildegard Hetzer und Kathe Wolf in Wien entwickelten und standardizierten 'Babytests.' Die Methode der Auswahl der Vpn. und die experimentellen Bedingungen wurden an den beiden Gruppen gleich gehalten. Eine Vp. wurd als 'Neger' betrachtet wenn die Eltern sozial als Neger galten, und man bemuhte sich nicht, den Grad der Neger- oder der weissen Vererbung einer bestimmtem Vp. abzuschätzen.

Vergleicht man die zwei Gruppen bezuglich des Entwicklungsquotients ('developmental quotient') [d.h., des Verhältnisses zwischen Entwicklungsalter ('developmental age') und Lebensalter ('chronological age')] so ergibt sich ein kleiner aber statistisch zuverlässiger Unterschied zu Gunsten der weissen Gruppe. Die Verbreitung der E.Q. (Entwicklungsquotienten) für beide Gruppen entspricht der einer Normalkurve von annähernd gleicher Variabilität. Die E.Q. der 60 Negersäuglinge erstrecken sich von 53 bis 123, und die der weissen Gruppe von 68 bis 142. Der mittlere quotient war bei der weissen Gruppe 105, (Normalabweichung, d.h. 'standard deviation' oder S.D., ±17) und bei der Negergruppe 92, (Normalabweichung ±16). Der Unterschied zwischen diesen Durchschnittszahlen ist etwa vier Mal so gross wie der Normalfehler ('standard error'). Die mittlere Zahl ('average score') der weissen Gruppe wurde von 28% der Negergruppe erreicht oder übertroffen, und die mittlere Zahl der Negergruppe von 71% der weissen

Gruppe erreicht oder übertroffen. Berechnete man den Prozentsatz der gelungenen Reaktionen auf die verschiedenen Testsituationen, so zeigte sich eine konsequente Tendenz zu Günsten der überlegenheit der Weissen. Von 100 Testsituationen erzielten bei 20 die Negersäuglinge und bei 76 die weissen den höheren Prozentsatz gelungener Reaktionen. Bei 4 Situationen war der Prozentsatz bei beiden Gruppen gleich. Eine Vergleichung der mindergewichtigen weissen Säuglinge mit den übergewichtigen Negersäuglingen erwies noch immer eine obwohl geringe Überlegenheit der Weissen,—ein Befund der die mangelhafte Ernährung als treffende Variable ('pertinent variable') auszuschliessen scheint.

Die Resultate dieser Untersuchung unterstützen keineswegs die Theorie, dass Negersäuglingen sich rascher entwickeln wie weisse Säulingen. Im Allgemeinen ist der von den Negersäuglingen in dieser Untersuchung erreichte Entwicklungsniveau ungefähr 80% so 'reif' wie der der weissen Säuglinge. Es ist von Bedeutung, dass sogar bei sehr jungen Säuglingen, und auch wenn die Einwirkungen der Umgebung auf das kleinste Mass reduziert worden sind, sich ungefähr die selbe Art von Unterschied und in ungefähr dem selben Masse zeigt wie sie sich früher bei Untersuchungen an älteren Versuchspersonen,—etwa Schulkindern oder Erwachsenen—finden liess.

McGraw

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GENETIC PSYCHOLOGY MONOGRAPHS

Child Behavior, Animal Behavior, and Comparative Psychology

AN EXPERIMENTAL STUDY OF PREHENSION IN INFANTS BY MEANS OF SYSTEMATIC CINEMA RECORDS*

From the Clinic of Child Development, Yale University

By

H. M. HALVERSON

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H. M. Halverson

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New Haven, Connecticut

CONTENTS

I

Introduction

The arm and hand of the newborn infant can be regarded as a more or less unorganized group of bones, muscles, tendons, skin, nerves, etc., but possessing the capacity of a highly cooperative and orderly functioning system. At least seven distinct senses, the muscular, tendinous, articular, warmth, cold, pressure, and pain, have their sense-organs generously distributed throughout this limb, particularly in the hand. It is natural, therefore, that this portion of the human body, with its advantage of location and its numerous sense end-organs, should be regarded as one of the most important *means by which the infant secures his first impressions of the world about him.*

The general physiological theory (30) regards the skin as the oldest sense-organ of the human body. As the covering of the body, it was the medium by which the animal learned of the outside world. As the animal moved about, certain of the forward parts of the body became specialized into sensitive regions to enable the animal to gain more specific information of its environment, and later the sensitive regions became the special sense-organs (68). This theory explains why the finger-tips, as well as the special sense-organs like the eye, ear, etc., are more sensitive than are other parts of the body. But, whether or not we accept the theory, we cannot disregard the findings of experimental physiology and psychology which indicate that the finger-tips have a high degree of tactual sensitivity.

The hand is of considerable consequence because of its generous sensory representation in the brain. In fact, the palm of the hand, the face, and the sole of the foot are, to speak loosely, our real tactile sense-organs, and, from both the practical and physiological points of view, the palm is, perhaps, of most service to us. In this connection, our attention goes immediately to Helen Keller for whom the hand performs as a worthy substitute for the eye and the ear. By means of her hand she reads and speaks our language and lives in a world quite similar to our own.

That there is a generous distribution of tactile sense-organs in the hand, there can be no doubt. Of some 2000 Pacini corpuscles scattered throughout the covering of the human body, the fingers alone contain 800 (68). The foot ranks second, and then follow in order the arm, the leg, and, finally, the trunk. These end-organs are found not only in the subcutaneous tissue but also in the bones, joints, and tendons, as well as in the interosseous membranes, and are generally supposed to function in response to pressure and cold.

Meissner's end-organs of pressure also are found in greatest numbers on the hand and foot, especially on the palmar surface of the tip of the index finger (68). Epidermal nerve-endings, organs of epicritic sensitivity, such as the finest nerve ramifications between the epithelial cells, and hederiform expansions, organs which probably respond to slight contacts, are plentiful in the palmar surfaces of the fingers.

We may support these discoveries by the experiments of Weber, of Goldscheider, and of von Frey on the

two-point limen (47). These three investigators agree that the threshold for the perception of two points varies for different portions of the skin, with the finger-tips and the tip of the tongue ranking first, and the middle of the back last.

Tactual localizations are made through the medium of "local signs." That is, one point on the skin differs from another point because their tactual qualities differ. The accuracy with which one may localize these points varies for different parts of the body, as in the case of dual tactual impression, and is greater for the fingers than for the back of the hand or the wrist, and is poorest on those portions of the body which are usually covered with clothing (47).

The senses cooperate in a most salutary manner to aid the individual in his development and to keep him in rapport with his environment. They may be classified as telesthetic and immediate. The former class includes vision and audition, while the latter includes the cutaneous and kinaesthetic senses. The former alone maintain at best a distant relationship with an object. The cutaneous sensations bring into this relationship an intimacy which is unmistakable. The desire for intimacy is perhaps the reason why infants reach for objects which stimulate their visual and auditory senses.

Place an object, as a cube, a few inches before a 16-weeks infant and note the behavior. He regards the cube for short intervals and generally makes sporadic, determined efforts with the arms and hands to reach for it, but is unsuccessful in his attempts to secure it.

A 28-weeks infant approaches and seizes the cube. His kinaesthetic and cutaneous senses cooperate in a

very definite, although somewhat clumsily immature, manner to aid in accomplishing the grasping act. At 52 weeks the infant secures the cube quickly, with little effort, and, analytically, in an almost artistic manner. In this learning process we find a gradual and steady growth in the ability of the infant to coordinate the several manipulatory elements of the arm so that they cooperate with vision in securing the cube. In this connection, another accomplishment is the partial conquest of the third dimension. No one can say just how distances appear to the unsophisticated eye of the young infant, but it is extremely doubtful that an infant early deprived of the use of his kinaesthetic and cutaneous senses would even half appreciate tridimensional space. These senses bring into early experience an appreciation of smoothness, roughness, hardness, softness, warmth, cold, distance, direction, size, etc., in a way that no other sense departments can supply. In fact, we may say that in early infancy the lower senses supply more practical and accurate information concerning the environment than do the higher senses. These lower senses aid the higher to make sure of themselves; for correct judgments as to the qualities of objects, such as hardness and softness, which at first are made only by means of the cutaneous and kinaesthetic senses, are later made on the basis of information supplied by vision. The object now looks soft or hard. Thus vision often serves as a surrogate for the cutaneous and kinaesthetic senses which originally contributed mutually to render the perception.

The importance of the cutaneous and kinaesthetic senses in securing information in our early perceptions

of space is illustrated in the cases of persons who, blind at birth, have recovered their sight later in life (47). They do not recognize by vision alone the shapes formerly perceived through the cutaneous and kinaesthetic senses and have to handle the objects to identify them. In the same way, they also make faulty judgments of distance and depth. We appreciate the prominent and valuable rôle of the eye and the ear, but we wish to render to the arm and the hand their just measure of attention. Without the functioning of the latter there would be great gaps in an individual's knowledge of the visual and auditory world.

The cutaneous and kinaesthetic senses are very closely and variably associated (49). An unexpected touch usually causes one to start, or to bring a hand toward the place contacted; or the touch may result in withdrawal, or in a defense attitude. No portion of the body of equal volume contains as many end-organs of the above modalities as does the hand. No other part of the body incorporates in as limited a section as many possibilities for varied action. First of all, consider the hand's great range of movement because of its suspension at the end of the arm. Note its freedom of operation due to the three joints of the arm and to the rotary action of the radius upon the ulna bone in the forearm. Consider the hand's manipulatory and exploratory qualifications by virtue of its five long digits with their fourteen phalangeal segments, the sensitive finger-tips, and the prehensile value of the opposition of the first to the remaining four digits. Consider the reach, strength, and flexibility of the fingers of the hand, also its ease, speed, and deftness in adapting its

form of grasp to the size, shape, weight, position, and even to the disposal of the object about to be prehended. The very close relation between the several cutaneous and kinaesthetic senses which one finds in the hand is what makes the hand the "feeler" of the human body.

In this study we may, with advantage, enumerate briefly some of the physiological and psychological conditions which are likely to be instated in the total act of prehension. They are: maintenance of bodily equilibrium, involving bracing by legs and heels; hip flexion, to bring the shoulders and head of the infant nearer the object; lowering of the head medially; rotation of the body above the hips to swing forward the favored side; extension of the lateral angle of the scapula, bringing forward the arm from the shoulder joint; extension and flexion of the elbow; wrist movements; hand-rotation; digital extension, flexion, and abduction; and thumb-opposition. Besides these conditions, there are direction of the approach, length and form of approach, its vertical profile, time elapsing between the presentation of the object and the start of the approach, time required to contact with the object, time required for grasp, kind of grasp, amount of displacement of object before it is grasped, and other conditions too numerous to mention at this time.

We do not propose to give in this paper a complete review of the literature on prehension (11). However, it may be said without fear of contradiction that all studies in prehension have merely scratched the surface. For example, no one can say definitely how infants of a given age will, under similar conditions, approach or grasp an object such as a cube, a pellet, a

ball, or a cylindrical object. We are, therefore, inclined to regard all investigations in this field as pioneer studies.

There are few well-controlled experiments on prehension, and almost all studies, as far as we know, consist of observations on one or two infants at more or less regular intervals during the first years of life. Among the best known works are those of Preyer (45) and Shinn (52), both of whom, before the close of the last century, explored not only reaching and grasping but many other forms of behavior, and those of Gesell, who has contributed more to the definition of the problem than any other worker in the field by virtue of his investigations in the prehension of specific objects. His results are crystallized in his two volumes (20, 21) on the growth of infants, which constitute a comparative inquiry into the reactions of infants of different ages in similar situations.

The utilization of a mechanical instrument capable of recording visually observable behavior makes possible analytic investigations of infant activity. No number of observers are as reliable as a motion camera for securing records of the behavior of infants. In thoroughness of detail, in scope, objectivity, permanence, and trustworthiness, the cinema record far outclasses human observation. The eye of the camera overlooks no detail of behavior within its range of observation, and, in addition, has foveal vision for this entire range (unless we except those objects which, by virtue of their distance, are out of focus), an outstanding advantage over the human eye. The camera has also a span of attention superior to that of man in that the

camera attends every detail of the scene before it. Psychologically, the camera is an ideal observer, a disinterested observer, who records behavior with utter indifference to its meaning or significance. The camera has an infallible memory. By projection it permits the re-enactment of a situation in full and accurate detail with respect to duration of time and sequence of events with a minimum of distortion of spatial schema. In fact, the camera improves upon the original situation in that one may repeat it at its normal speed, slow speed, or by successive stills. Study by slow motion and by stilling the individual frames of the motion film form the greater part of our investigation.

In an analytic study, such as the present one, it is absolutely necessary to review a situation time and time again. Under ordinary conditions, of course, one cannot reinstate a given situation (57). The situation concerns not only the external conditions but also the attitude (56) of the infant, and, even though we succeed in controlling the former, we are not likely to reproduce in exactness the latter. No one can say that the infant's attitude upon the reinstatement of what is apparently the same external situation is the same attitude which he experiences in the original situation. The motion camera, however, as far as one knows, closely reproduces the original situation and permits one to study it at length. No observer, be he ever so skilled, can sketch with any degree of reliability the details of an infant's behavior while he is actively engaged in prehension. One catches crudely a bit of the action on the wing, and, on recording it, is immediately assailed with doubts and misgivings concerning its ori-

gin, course, and end. Certainly the span of attention is indeed limited.

However, when one has completed the analysis of the motion-picture records, it is relatively simple to distinguish with the eye alone one kind of behavior from another, such as recognizing the form of approach or the type of grasp which an infant utilizes in prehending an object.

II

THE EXPERIMENT

Method, Subjects, Procedure

The experimental study of prehension herewith presented was undertaken in the photographic observatory (24) of the Yale Psycho-Clinic, which, with its special arrangements and equipment for observing and photographing the infant, reduces to a minimum interference with his characteristic behavior.

The study is both a motion and frame-by-frame analysis of the cinema records of infant prehension of red cubes measuring one inch on an edge, and is both qualitative and quantitative in nature. The paper also introduces some photographic techniques for the purpose of analyzing and resolving human behavior into temporal and spatial patterns.

The subjects of investigation are twelve or more infants at each of the following ages: 16, 20, 24, 28, 32, 36, 40, and 52 weeks.

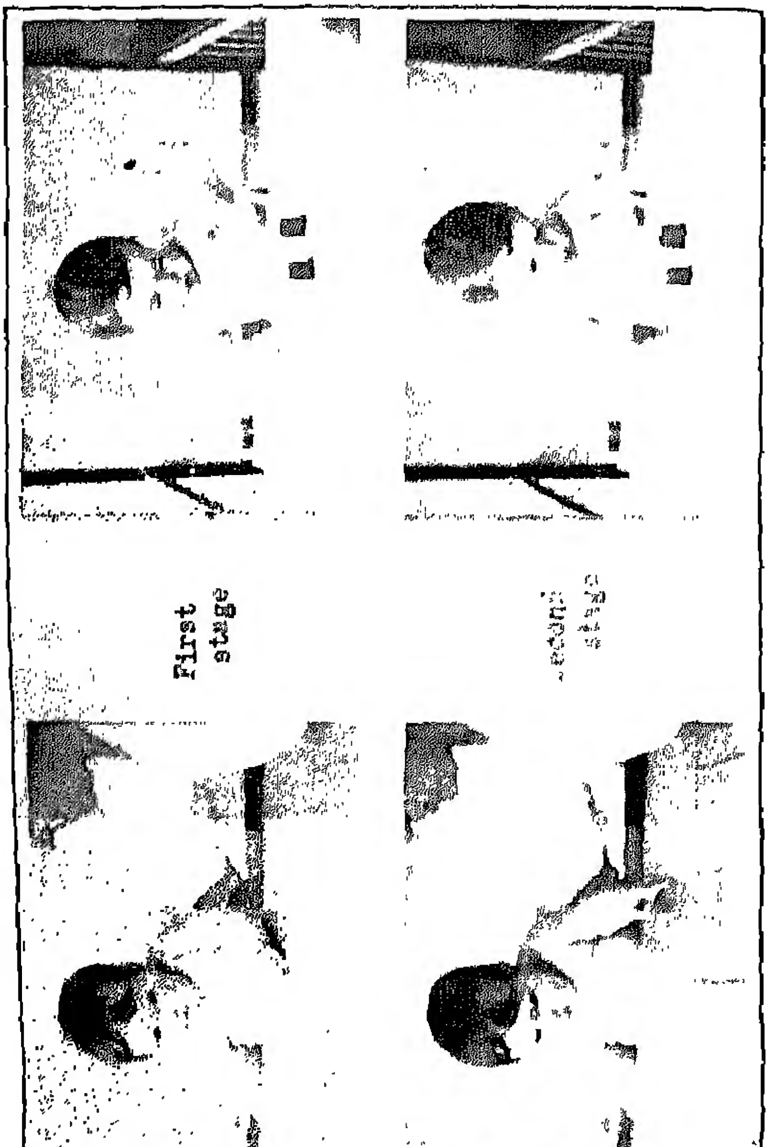
The cube situation is but one of the many test situations used in the normative examination of infants. Our subjects are selected from those who by this examination indicate that they are developing normally. In order to secure infants who are most likely to be of average development, we include only those whose fathers fall within the middle 50% of the general adult population as determined by the Barr rating scale (55). The education of both parents is generally that of the grammar school. The infants are of Teutonic or of

Celtic race, are well nourished, and the records of each reveal a normal gestation term, an approximately average birth weight, and the absence of any serious illness since the time of birth.

The procedure for the study of cube prehension is as follows. When the infant arrives at the clinic and the usual precautions with regard to his physical condition are exercised, he is brought into the photographic observatory, is relieved of all clothing, and given opportunity to adjust to his environment before the regular normative examination starts. The regular examination is about one-fourth completed when the cube situations are instated, thus providing a warming-up period and complete adaptation without apparent fatigue.

The infant is seated on the platform (30 inches in height) of the experimental crib before, but not touching, a table top which is supported elbow high on the crib's adjustable side rails (see Figure 2). The young infant who cannot maintain a sitting equilibrium is placed in a small, specially constructed Morris chair with a supporting belt about his waist (see Figure 1). This arrangement is elastic enough not to interfere greatly with forward or lateral movements of the trunk.

The infant faces the longer edge of the table-top, which is 30 by 20 inches, and is divided laterally into six equal lanes by lines which extend from its further edge to a horizontal line parallel with, and 6 inches from, the near edge (see Figure 1). These lines, which aid materially in the analysis of the records, have in no way, as far as we can determine, interfered with the infant's natural behavior toward or with the cubes. The infant exhibits no self-consciousness in performing his


First stage

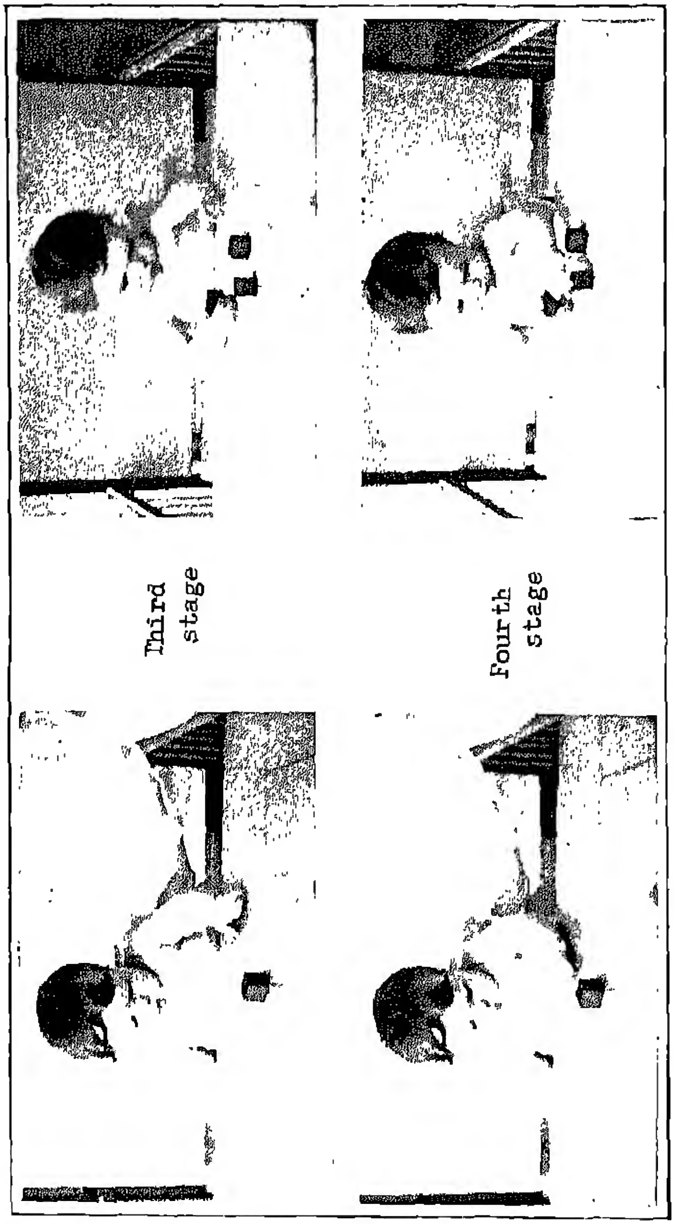
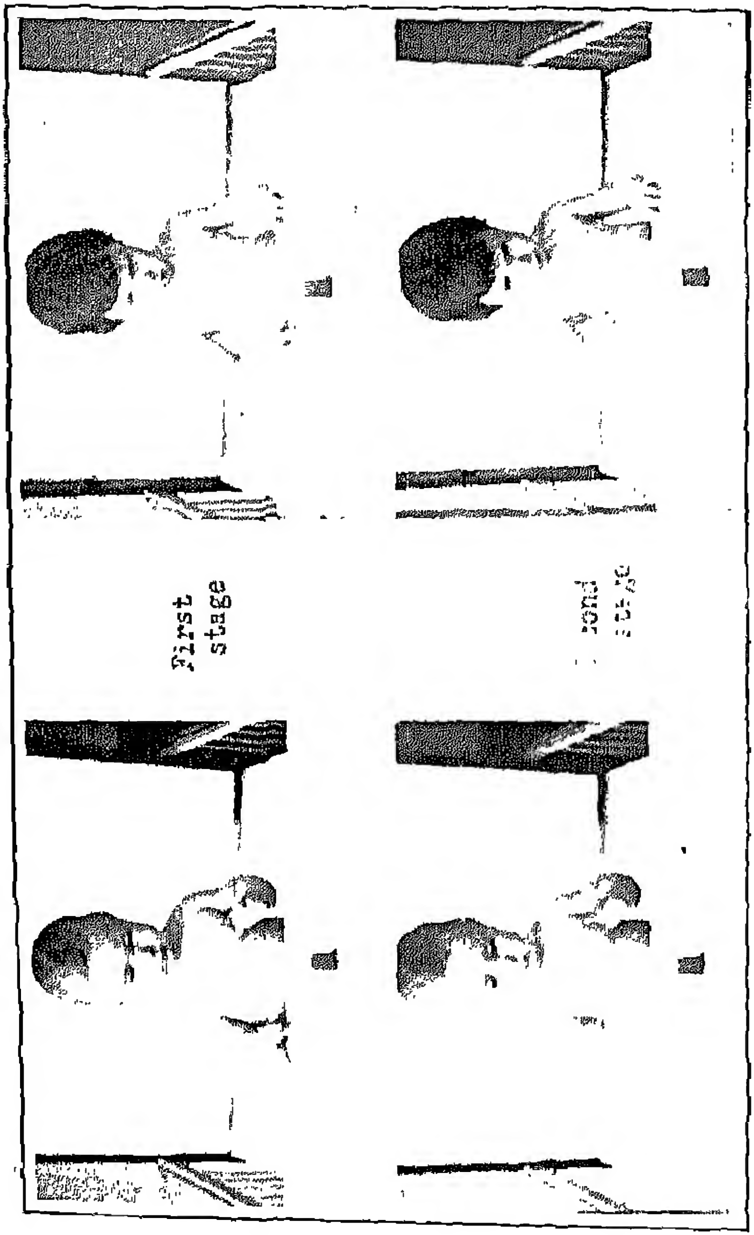
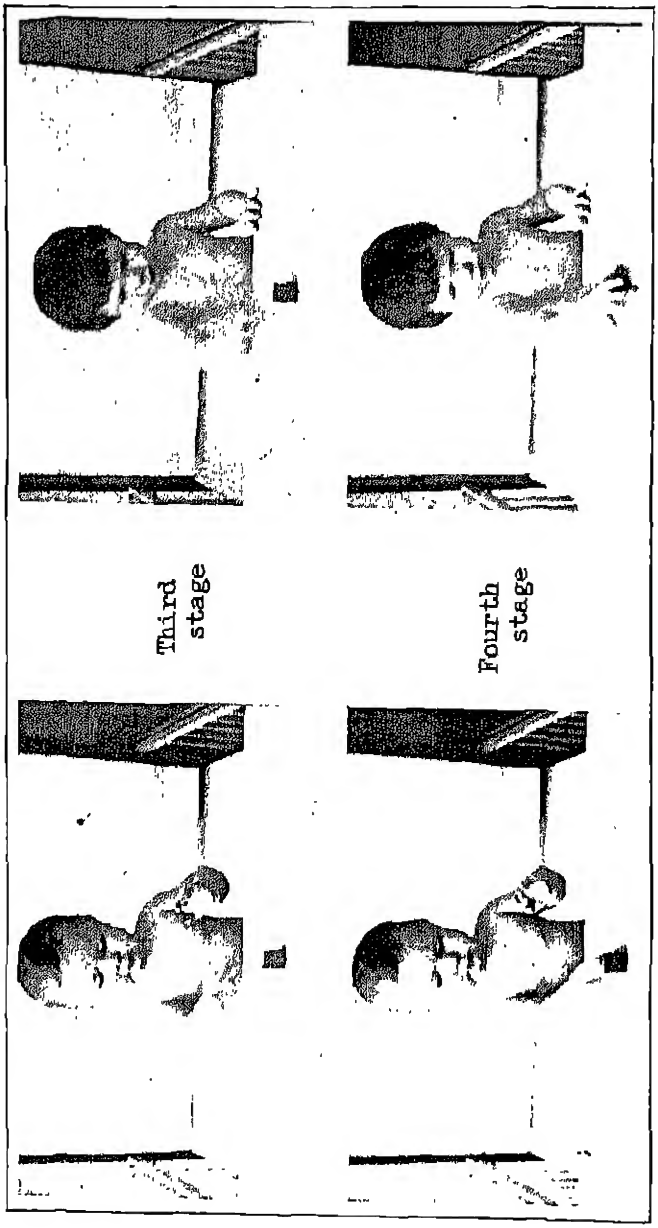


FIGURE 1

ILLUSTRATING TWO TYPES OF APPROACH: THE ANGULAR CIRCUITOUS SLIDE APPROACH AND THE VERY CIRCUITOUS LOOP APPROACH


First stage



A. Slightly circuitous planing approach

B. Straight planing approach

FIGURE 2

ILLUSTRATING TWO TYPES OF APPROACH: THE SLIGHTLY CIRCUITOUS PLANING APPROACH AND THE STRAIGHT PLANING APPROACH

task and enjoys the full free play of trunk and limbs, untempered by inhibitions, in his reactions to the cube before him.

There are three cube situations, each of 20-seconds' duration. In the presentation of the first cube, the examiner (*E*) stands on the left side of the crib, facing it, takes a cube in the palm of her left hand and carries it below the table top to the median plane of the infant. She then takes the cube between her thumb and two first fingers and taps it against the far edge to draw the infant's regard to this point. As the infant, for the first time, fixates the cube, it is advanced along the median line at a rate which brings it to the standard median position, a point 6 inches from the near edge, in 2 seconds. *E* then releases the cube so that one of its surfaces fronts the infant. If, within 9 seconds, the infant gives no indication of reaching for the cube, or appears unlikely to touch it, *E*, at a signal from the operator (*O*) outside the observatory, advances the cube 3 inches nearer the infant and again releases it. If, at the ninth second, the infant appears likely to touch or take the cube, the cube is not moved forward until the next signal, at 14 seconds. Of course, if the infant grasps the cube before the ninth second, *E* does nothing further with it. Thus any infant who does not acquire the cube within the first 10 seconds (it takes one second for *E* to reach the cube at nine and another to advance it to the near position) is given a second chance to prehend the cube at a point easily within his reach.

This procedure is repeated in presenting the second and the third cubes, with the exception that the second cube is presented with the infant holding the first cube

in his left hand, and the third cube situation starts with a cube in either hand. The interval between successive cube instatements is about two minutes.

A motion-picture camera, encased in a near sound-proof box and aimed at the infant from an angle of 50° above the horizontal in the front median plane, records the infant's behavior. A second camera, at ear level and at right angles with the first camera, is used judiciously to furnish supplementary photographic records (24).

Method of Studying Records

The apparatus for studying the motion film is a projection table (26) which we constructed especially for this form of analytic work. The projector is an Eastman, 6-volt, hand-cranked, Model C Kodascope, which is equipped with a one-inch lens. It is mounted beneath a table, within easy reach of the left hand, in such a manner that, with the aid of a mirror, it projects a 2½-inch by 3-inch image of the motion film upward on the ground-glass set in the lower left-hand corner of the table top, which tilts forward 30°. We reconditioned the Kodascope, which normally permits the film to move forward only in the film channel, to permit film movement backward as well as forward by the adjustment of the teeth of the shuttle and by the addition of two take-up pulleys at either end of the film. One may operate the projector with the left hand to obtain any speed of movement of the film from discrete motion to about 32 exposures per second, and to "still" the individual frames of the motion picture for

an indefinite period without damaging the film. This arrangement leaves the right hand free for recording and tracing. The ground glass is lined or marked as the occasion demands in order to facilitate definition of direction and distance. Occasionally we remove the ground glass in favor of clear glass and place upon it a paper so that the image thrown upon the latter may be traced and retained for future reference. One revolution of the crank exposes successively eight frames and the staccato clicking of the shutter makes counting of the frames an easy matter. The incorporation of this compact projection unit into the study table greatly simplifies the analysis of the motion-picture film.

The combination of the visual records of the cameras, the glass screen, and the lined table top before the infant enables us to describe his behavior in spatial-temporal patterns.[1] For example, in plotting the route which the infant's hand takes in approaching a cube, as represented by the film of the front camera, we "still" successively each frame in the approach, and, with the tip of the index finger as the point of reference, map out, on a reproduction of the ruled table top drawn to scale, each step in the progress of the hand until it contacts with the cube or ceases to advance. We obtain the time required to make this approach by counting the number of frames involved in the complete act.

[1]The cameras used in this experiment were first timed (25) and then carefully adjusted to give equal speeds of operation. Each camera runs for 40 seconds before it is rewound. The reduction of speed per second during this interval for the first camera is exactly one frame while the reduction of speed for the second camera for the same interval is .9 of a frame. A retiming of one of these cameras after three years of laboratory use shows that it has lost nothing in its initial speed and smoothness of operation.

The record of the second camera serves as a check against the above film and enables us to route fairly accurately the vertical profile of the hand on the approach. This record also shows, among other things, the amount of forward head and body displacement as the infant advances upon and prehends the cube.

In analyzing our material we used four forms which outline in detail our four-way attacks in studying the motion-picture film (see footnote 2, page 132). Form 1 is a squared paper with the items of investigation listed at the left margin. The duration of a situation (20 seconds) is presented in spatial terms on the abscissa, the distance between each successive ordinate having the value of one second. By lines and signs on the abscissa we denote the time of the initiation of any of the several behavior reactions indicated at the left, its duration and its end, so that the completed graph delineates the activities of an infant for a given situation. At the bottom of Form 1 are two figures which are drawn to scale to represent the table top; on these are plotted the route of the hand in reaching for the cube and the range of movement of both hands.

Form 2 details numerous items of the mechanics of prehension which are involved in reaching for, grasping, and manipulating the cube. Forms 3 and 4 represent a more detailed inquiry into specific aspects of the approach and manner of lifting the cube from the table.

Genetically, there are in this study three principal forms of behavior which command our particular interest: (*a*) the nature of visual attention (regard) of infants, (*b*) the manner in which infants reach for (approach) the object, and (*c*) the manner in which in-

fants grasp. Then we investigate the relation between regard and grasp, and the influence of the form of approach upon the type of grasp. Besides these inquiries, we note the duration and the order of regard for objects about the infant, the number of attempts to reach the cube, the number of failures and successes in these attempts, changes in the direction of the approach during the advance upon the cube, the rate of the advance, the stages in the approach, the vertical profile and height of the hand during the approach, hand-rotation, amount of time required to seize the cube, the actual grasping-time, the number of hand adjustments required to grasp the cube firmly, the amount of cube displacement before it is gripped, the effect of the presence of additional cubes upon the infant's behavior to the cube presented, and many specific reactions of developmental importance.

In order to better comprehend the behavior reactions of the infants in the three different cube situations and to facilitate our study of the data secured from the analysis of the motion film, we combine the results obtained by means of the four forms into the numerous tables and graphs which we present forthwith.[3]

[3]The Yale Psycho-Clinic will keep on file and make available to special investigators the more complicated tabular data which it has not been possible to print in this monograph. These data include detailed material on the following general topics: method of analysis of motion-picture films, nature of regard, regard for cube and explicit reactions to it, the approach, vertical profile of approach, method of lifting and disposing of cube, aim of the forearm and aim of the hand during approach, touching and grasping, additional facts concerning grasp, and specific infant activity.

III

EXPERIMENTAL RESULTS

After careful consideration, we find that the median is, with few exceptions, best representative of the central tendency for the various functions presented in the tables and graphs, because in many of the groups, particularly the younger age groups, one or two measures of extreme value distort the average so that it is entirely unrepresentative of the group scores. Hence, in reviewing the tables and graphs, unless otherwise specified, the median forms the basis for comparison between the several age groups.

NATURE OF REGARD

Briefly, the records of the 16-weeks infants show that, in general, a short regard for the cube at the start of the situation is usually followed by a second short regard after the cube is moved to the near position. There are exceptions to this rule, of course. The initial regard at 20 weeks is usually of longer duration than the first regard of the 16-weeks group, and the 20-weeks infants are likely to regard the cube again, at least once and sometimes oftener, but these regards occur at irregular intervals during the situation. At 24 weeks there is generally a more prolonged first regard for the cube and greater perseveration of visual attention than at 20 weeks. At 28 weeks the first regard is of longer duration than at any other age. In six of thirteen cases the first regard lasted throughout the entire situation. Perseveration of regard is shown in the

fact that in the remaining seven cases the regard always returned to the cube. At 32 weeks there is always the first regard which begins at the initiation of the situation. The duration of this regard varies greatly within the group, and there is considerable falling off in perseveration and total amount of regard. At 36 weeks there is again a considerable variation in the duration of the first regard with an increase in perseveration and total regard. At 40 weeks the duration of the first regard is considerably less, on the average, than that of the 36-weeks group, although the standard deviation is high. At 52 weeks the initial regard is even shorter than at 40 weeks and the variation within the group much smaller.

The first graph of Figure 3 presents the median of each age group for the duration of the total regard, the average duration of regard, and the duration of the first regard for the first cube. The total regard for the eight age groups increases quite steadily from 4.5 seconds at 16 weeks to 18.0 seconds at 28 weeks, after which there is a sharp fall in the curve to 10.0 seconds at 32 weeks, followed by an increase to 14.0 seconds at 36 weeks, and a general decline from this point to 10.75 seconds at 52 weeks. The increase in total regard shown for the first four age groups is very likely what one might expect. At 16 weeks there is less regard for the cube than there is for the hand and table top and other objects about the infant (Table 4). At 20 weeks there is greater regard for the cube, in fact, almost as much as there is for all other objects together. At 24 weeks the cube assumes major interest for the infants and at 28 weeks its interest is practically all-consuming.

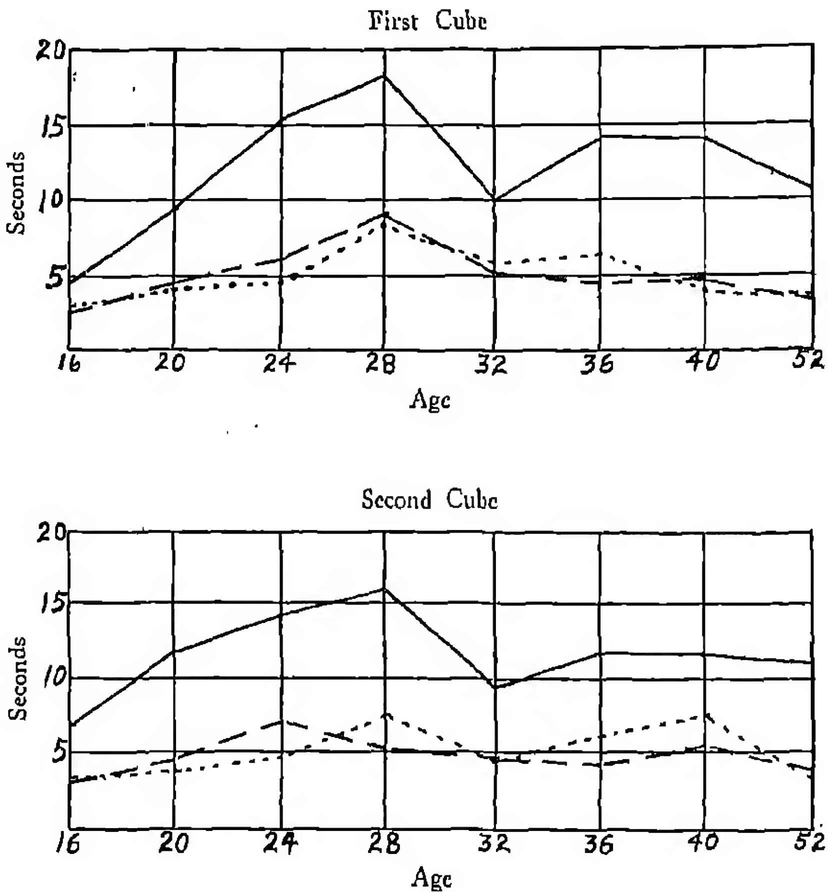


FIGURE 3

MEDIANS OF THE TOTAL DURATION OF THE FIRST REGARD, THE DURATION OF THE TOTAL REGARD, AND THE AVERAGE DURATION OF THE INDIVIDUAL REGARDS FOR EACH OF THE THREE CUBES FOR EACH AGE GROUP

Total regard ————

Average duration — — — — —

First regard - - - - - -

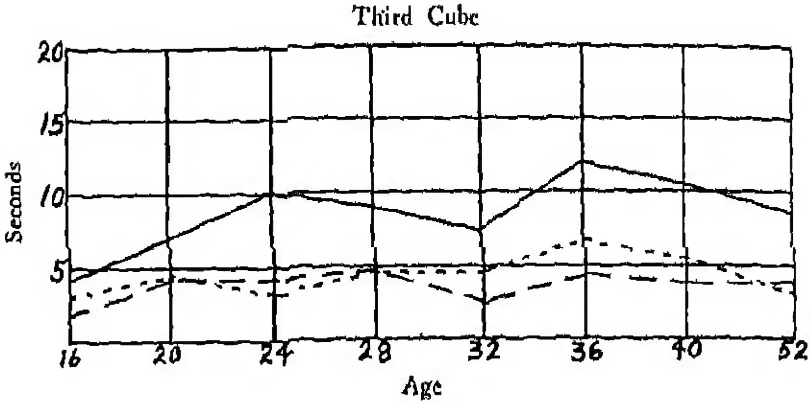


FIGURE 3 (*continued*)

MEDIANS OF THE TOTAL DURATION OF THE FIRST REGARD, THE DURATION OF THE TOTAL REGARD, AND THE AVERAGE DURATION OF THE INDIVIDUAL REGARDS FOR EACH OF THE THREE CUBES FOR EACH AGE GROUP

Total regard ————

Average duration — — — — —

First regard - - - - - -

An analysis of other data aids us in the interpretation of these results. Naturally, one expects the duration of regard for the 16-weeks infant to be less than that of the 24-weeks infant, and so on. We find, however, that no 16-weeks infant grasps the cube. In fact, there are only three contacts and no pursuits (table showing these facts is not given), while at 20 weeks there are five contacts with the cube and three pursuits after contact, which result in three repetitional contacts and one grasp. At 24 weeks there are six contacts followed by six repetitional contacts, five grasps, and one primitive squeeze; while at 28 weeks there are eleven contacts with eleven repetitional

contacts and twelve grasps out of thirteen attempts. There are other items also which aid in the explanation of the increase of the duration of the regard with advance in age. At 16 weeks the regard is always for the cube, which is seldom touched and never grasped—an unattainable object. At 20 weeks the regard is for the cube, which is touched but five times and grasped but once, so that the regard again is generally for the unattainable object. At 24 weeks only five of thirteen infants secure the cube (the time up to grasping being 11 seconds) so that the regard is still principally for the unattainable object. However, of the five infants who secure the cube, the median duration of regard preceding grasp is 9 seconds, while the median duration of the regard for the grasped cube is 8 seconds. At 28 weeks, 6.25 seconds (median) are required to grasp the cube, and every infant uses this entire time in regarding the cube before obtaining it. These infants also regard the cube for 6.5 seconds after securing it. Thus we find an additional item of regard for the 24- and 28-weeks infants, namely, inspection of the cube following grasp, a more intimate form of regard which brings the visual, cutaneous, and kinaesthetic senses to play upon the cube. The 28-weeks age is the high point for visual attention with respect to both the free cube and the cube in hand.

An investigation into the data of Tables 18 (see *Superior-palm*) and 19 (see *Actual grasp-time* for 28 and 32 weeks) partly explains the cause for the sharp decline in total regard time and in average duration of regard from 28 weeks to 32 weeks. At both 28 weeks and at 32 weeks the predominating type of grasp is the su-

perior-palm grasp. With the thumb and forefinger becoming prominent at 28 weeks, the infant undoubtedly feels the urge for using these members of the hand in grasping. He slowly and awkwardly accomplishes this type of grasp, which is entering the picture for the first time. The actual time required to grasp the cube at this age is 20.5 frames, i.e., 1.28 seconds, and the time which elapses between the beginning of the situation and the point at which grasp begins is over 6 seconds. At 32 weeks this type of grasp is pretty well mastered and is performed with celerity, for the actual time required to grasp the cube is 9 frames, i.e., a trifle over one-half second, while the time elapsing between the beginning of the situation and the moment at which grasp starts is 3.0 seconds. Now, for both these age groups the regard for the cube up to the time of procuring it is of practically equal duration, but having seized the cube, at 28 weeks, the infants continue to inspect the cube for over 6 seconds, while the 32-weeks infants inspect it for only 2 seconds. Therefore, there is a dual cause for this sharp decline in the curve from 28 weeks to 32 weeks. First, the older age group secures the cube in less time than does the younger age group, thereby shortening the regard for this period; and, secondly, the older age group ceases its inspection of the cube sooner than does the younger age group. At 36 weeks the curve for total regard takes a rather abrupt upward trend. The infants of this age group use the inferior-forefinger grasp as the main type of grasp, a distinct advance over the superior-palm grasp. However, the infant requires more time to get ready for this grasp (4 seconds) and at the same time the actual grasping time

is greater than that of the preceding age group. The regard before grasping for this group is 4 seconds and the regard after grasping is 3 seconds. Undoubtedly, the position of the cube against the finger-tips introduces new elements in grasping which result in regarding the cube for a longer time after it is held. The gradual decline in the curve from 36 to 40 weeks occurs because the predominating type of grasp for the 40-weeks group, which is the same as that of the 36-weeks group, is accomplished earlier in the situation and is performed with greater ease and in a shorter time than it is carried out in the case of the 36-weeks group. For example, the duration of the regards before and after grasping are, for the 40-weeks group, only 3 seconds and 2 seconds, respectively. At 52 weeks there are two leading types of grasp, the inferior-forefinger and the forefinger, the differences between which are positional rather than fundamental (see pages 218-219). In any case, the duration of the regard before grasping the cube, 2.75 seconds, and the regard after grasping, 1.5 seconds, is less for this age group than for any other group. The time up to the grasp is but a trifle greater than that of the 40-weeks group, while the actual time required to grasp the cube is only 5½ frames, considerably less than one-half second.

Table 1 shows the number of infants regarding the various objects in the three cube situations and the duration of their regard. The left half of the table gives the number of infants of the different age groups in the order in which they regard the objects. The three different cube situations are indicated across the top of the table above the vertical columns containing

TABLE 1

Number of Infants Regarding the Various Objects in the Three Cube Situations and the Duration of Their Regard

Number of infants regarding

Age (weeks)	Regard order	First cube: Cube	Hands	Table	Examiner	Dome	Second cube: Cube	Other cube	Hands	Table	Examiner	Dome	Third cube: Cube	Other cube	Hands	Table	Examiner	Dome
16	1	10	0	0	1	1	9	1	0	0	1	1	10	0	1	0	0	0
	2	1	2	5	3	1	2	2	3	1	3	1	1	1	2	4	0	3
	3	4	2	2	2	2	5	0	1	1	3	1	3	1	1	0	3	2
20	1	11	0	0	2	1	12	1	1	0	0	0	9	2	0	1	0	0
	2	0	1	3	6	3	2	2	1	2	5	1	1	1	4	0	3	1
	3	8	1	2	1	1	4	1	3	1	0	3	1	5	0	0	3	1
24	1	12	0	0	1	0	11	2	0	0	0	0	10	2	0	0	0	1
	2	1	2	1	5	3	2	3	2	1	0	4	3	6	1	0	1	2
	3	8	0	1	0	2	6	1	0	1	1	1	3	4	0	0	2	0
28	1	13	0	0	0	0	11	1	0	0	0	1	8	3	0	0	0	2
	2	0	0	1	2	1	1	6	0	0	0	3	5	6	0	0	0	2
	3	6	0	0	1	0	6	1	0	0	2	0	7	1	0	0	0	2
32	1	12	0	0	0	0	11	0	0	0	1	0	9	0	0	0	1	0
	2	0	0	0	1	10	1	5	0	0	2	3	1	5	0	0	1	2
	3	3	1	0	5	0	6	1	0	0	1	2	3	0	0	0	2	1
36	1	11	0	0	0	1	12	0	0	0	0	0	12	0	0	0	0	0
	2	1	0	0	3	4	0	5	0	0	0	4	0	7	0	0	0	5
	3	8	0	0	1	1	11	5	0	0	0	1	9	2	0	0	1	0
40	1	12	0	0	0	0	12	0	0	0	0	0	11	1	0	0	0	0
	2	0	0	1	3	1	0	6	0	0	3	3	1	6	0	0	4	0
	3	8	0	0	2	1	5	0	0	0	2	1	9	0	0	0	1	1
52	1	12	0	0	0	0	12	0	0	0	0	0	12	0	0	0	0	0
	2	0	0	0	5	5	0	0	0	0	0	10	0	1	0	0	1	10
	3	9	0	0	1	1	6	1	0	0	1	0	7	2	0	0	2	0

Duration of regard (seconds)

Age (weeks)	Regard order	First cube: Cube	Hands	Table	Examiner	Dome	Second cube: Cube	Other cube	Hands	Table	Examiner	Dome	Third cube: Cube	Other cube	Hands	Table	Examiner	Dome
16	1	57.0	0.5	0.0	4.0	4.5	33.0	2.0	0.0	0.0	2.0	7.0	36.0	0.0	4.5	0.0	0.0	0.0
	2	3.0	6.5	28.0	6.0	13.5	2.0	10.0	21.5	3.0	18.0	2.0	0.5	2.0	20.5	14.5	0.0	15.5
	3	9.0	2.0	7.5	14.5	7.5	19.0	0.0	4.5	8.5	19.5	4.0	14.0	4.0	5.5	0.0	18.5	4.0
20	1	69.5	0.0	0.0	3.5	6.5	75.0	8.0	7.5	0.0	0.0	0.0	73.5	3.5	0.0	2.5	0.0	0.0
	2	0.0	3.0	15.5	21.0	12.0	13.5	6.0	0.5	4.5	38.0	6.0	5.5	6.0	19.0	0.5	6.5	6.0
	3	55.5	3.0	4.5	3.5	1.0	21.0	1.5	17.5	1.5	0.0	0.0	18.0	24.5	0.0	0.0	4.5	2.0
24	1	77.5	0.0	0.0	1.5	0.0	67.0	13.5	0.0	0.0	0.0	0.0	52.0	12.0	0.0	0.0	0.0	10.0
	2	18.5	12.5	1.0	13.5	11.0	23.5	11.0	3.5	6.5	0.0	9.5	23.0	23.5	1.0	0.0	6.5	3.0
	3	44.5	0.0	3.5	0.0	4.5	43.0	1.5	0.0	3.0	7.0	1.0	30.0	22.0	0.0	0.0	5.5	0.0
28	1	139.0	0.0	0.0	0.0	0.0	113.0	0.0	0.0	0.0	0.0	4.0	41.0	19.5	0.0	0.0	3.0	54.0
	2	0.0	0.0	4.0	6.5	11.5	3.0	37.5	0.0	0.0	0.0	9.0	32.5	42.0	0.0	0.5	0.0	3.5
	3	52.0	0.0	0.0	1.0	0.0	23.5	1.0	0.0	0.0	2.5	0.0	21.0	6.5	0.0	0.0	0.0	6.5
32	1	86.0	0.0	0.0	0.0	0.0	78.0	0.0	0.0	0.0	2.0	0.0	79.0	0.0	0.0	0.0	1.0	0.0
	2	0.0	0.0	0.0	7.0	48.5	8.5	31.5	0.0	0.0	8.5	9.0	1.5	31.0	0.0	0.0	3.0	9.5
	3	6.5	1.5	0.0	30.5	0.0	23.5	0.0	0.0	0.0	3.5	8.5	6.0	0.0	0.5	0.0	7.0	2.0
36	1	94.0	0.0	0.0	0.0	1.5	74.0	0.0	0.0	0.0	0.0	8.0	51.5	0.0	0.0	0.0	0.5	0.0
	2	5.5	0.0	0.0	19.0	11.0	0.0	19.5	0.0	0.0	0.0	15.0	0.0	17.5	0.0	0.0	0.0	6.5
	3	48.5	0.0	0.0	1.5	3.5	35.0	0.0	0.0	0.0	0.0	1.0	13.0	8.5	0.0	0.0	2.0	0.0
40	1	79.0	0.0	0.0	0.0	0.0	75.5	0.0	0.0	0.0	0.0	0.0	83.5	1.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	1.5	7.0	30.0	0.0	10.0	0.0	0.0	5.0	12.5	4.5	15.0	0.0	0.0	9.0	0.5
	3	42.0	0.0	0.0	2.5	3.0	18.0	0.0	0.0	0.0	5.5	5.0	38.0	0.0	0.0	0.0	1.0	1.0
52	1	58.5	0.0	0.0	0.0	0.0	78.0	0.0	0.0	0.0	0.0	0.0	63.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	18.5	9.0	0.0	0.0	0.0	0.0	0.0	52.5	0.0	4.0	0.0	0.0	2.5	35.0
	3	36.5	0.0	0.0	1.0	4.0	37.5	1.5	0.0	0.0	2.0	0.0	12.0	10.0	0.0	0.0	7.0	0.0

the names of the objects. The figures in the extreme left column of the table signify the age group, the next column to the right (reading down) gives for each age group the order (1, 2, and 3) of the first three regards, and the figures in the remaining cells of the table indicate the number of infants who regard the different objects at any one of the three regard periods above mentioned.

The right half of the table reads in the same manner as the left half except that the figures in the individual cells now indicate the total time in seconds that the infants regard the different objects during any one of the first three regard periods. For example, the first cell in the column labeled *Cube* in the left half of the table shows that in the first cube situation ten of the 16-weeks infants select the cube for the first object of regard, while the first cell in the right half of the table indicates the total number of seconds (37.0) that these infants looked at the cube during their first regard.

We find an increase in the duration of the first regard for the cube up to 28 weeks, after which a decline occurs with the low point at 52 weeks (see Figure 3, and Table 1 under *Duration of regard, first cube*). While the first regard is of greatest duration at 28 weeks, its variability at this age is also highest; some of the infants regard the cube for very short intervals, while six of the group regard it steadily throughout the entire situation.

Similarly, the average duration of the individual regards, as well as the standard deviation for these measures, is greatest for the 28-weeks group.

None of these figures are to be regarded as true measures of the capacity of the infants of the various age groups to visually attend an object of the size of a cube; nevertheless, the figures are significant, because, under the conditions of our experiment, they show the exact duration value of the regard and its degree of variability and give some indication of what one may expect of infants under similar conditions.

Regardless of how we view the measures in Tables 1 and 4, and in spite of the high values of the standard deviation in most cases, the infants of the 28-weeks group have the longest single regard and the highest total regard for the cube, while, in general, the more remote from this point are the age groups, the greater is the decrease in regard. Of course, it is perfectly plausible to believe that the infant regards the cube at different times for different reasons. He may regard it purely because it attracts the eye, perhaps by its color, or because the cube is something he wants. Then, after he procures the cube, his regard may be due to the tactile or kinaesthetic qualities which are involved in holding the cube, or because he can use it, or for other reasons.

Perhaps we should attempt to explain why regard occurs as it does in this study. The increase in the duration of regard may be due to: (*a*) improved vision, (*b*) increase in attentional capacity, (*c*) the presence of the unfamiliar object (lure of the unknown), (*d*) the stimulation afforded by touching the cube, (*e*) greater intimacy due to grasp, (*f*) fundamental changes in the type of grasp. The decrease in the duration of the re-

gard may be due to: (*a*) the ease of procuring the cube and (*b*) the infant's growing familiarity with it.

We are inclined to believe that the increase in regard from 16 to 20 weeks may be explained in terms of improved vision, increase in attentional capacity, the lure of the cube with which the infants are unfamiliar, and the added stimulation due to touching the cube. The regard of the 16-weeks infant for the cube as it lies on the table is not in the least fortuitous, but whether he actually sees the cube as a cube or merely as the only interruption in the continuity of the unbroken homogeneous surface of the table top, is open to question. The regard, as it shifts about on the table, stops at the cube and lingers before it passes on. While we cannot be certain that there is an actual improvement in vision, our observations indicate that the 16-weeks infants stare at the cube while the 20-weeks infants actually regard it for longer intervals of time with more or less definite fixation. The records show that touching the cube in the effort to procure it does elicit further attempts to contact with it again. Of the three infants who contact with the cube, all three pursue and contact with it again. Preyer (45) states that his infant at 17 weeks grasps at objects far out of reach.

While the superiority of the 24-weeks group over the 20-weeks group is largely due to the added stimulation of touching the cube and grasping it, it is likely that there is some increase in attentional capacity favoring the 24-weeks group as well as some slight improvement in vision. Five infants of the 24-weeks group contact with the cube, and five grasp it. We also find that of the six infants who at first only touch the cube

all pursue it and are successful in reaching it again. The five infants who grasp the cube inspect it for 8.0 seconds (median) after grasping. The advantage in regard of the 28-weeks group over the 24-weeks group is due, as far as we can determine, to the fact that more infants touch and grasp the cube. Eleven infants, after touching the cube, continue to pursue it, and of these only one fails to retouch it. Twelve of the thirteen infants grasp the cube and follow this with 6.5 seconds of immediate inspection.

The decrease in the amount of regard from 28 to 32 weeks is perhaps due in part to the fact that increased opportunity for inspecting the cube is overcome by familiarity with it and the ease of procuring it. The increase in regard from 32 to 36 weeks is due to a fundamental change in the type of grasp (see pages 218-219) which increases the difficulty of obtaining the cube and thereby lengthens the duration of the regard before grasping. The steady decrease of regard from 36 to 52 weeks is due to greater facility in approaching and grasping, and perhaps to familiarity with the cube.

Figure 3 presents graphically the median of each age group for the duration of the first regard, the duration of the total regard, and the average duration of the individual regards for the first cube, the second cube, and the third cube, respectively. An examination of the graph on the first cube shows the increase in the total regard duration from 16 to 28 weeks. The curve then declines sharply to 32 weeks, after which there is some increase at 36 weeks, followed by a slight decline for the 40- and 52-weeks groups. The curve of total regard duration for the second cube is almost identical in

form with that for the first cube. For the third cube, however, the curve for total regard duration rises from 16 to 24 weeks and then declines somewhat to 32 weeks with a sharp rise to 36 weeks and a general falling-off from this point to 52 weeks. In general, then, the forms of the curves for the duration of total regard for the three cubes differ essentially only for the 28-weeks group for the third cube, for it is only for this cube that this group fails to regard the presented cube longer than any other group regards it.

The curve for the median duration of the first regard for the first cube increases from the 16-weeks group to the 28-weeks group and, in general, declines for the remaining age groups. The curve for the first regard for the second cube is similar to the curve of the first regard for the first cube except that there is an increase in the amount of duration of the first regard at 40 weeks. In the case of the third cube the curve of the first regard, in general, increases from 16 weeks to 36 weeks and then declines for the remaining age groups. Thus, the 36- and the 40-weeks groups give a more prolonged first regard for the third cube than do the remaining groups.

The curve for the average duration of individual regards for the first cube shows that the duration of these individual regards increases from 16 weeks to 28 weeks and then declines to 52 weeks. In the case of the second cube this curve increases from 16 weeks to 24 weeks and declines slightly for the remaining age groups with the exception of a slight rise at 40 weeks. In the third cube situation the average duration increases from 16

to 28 weeks and remains fairly constant except for a decline at 32 weeks.

The total amount of regard, then, for the third cube (Figure 3, *Third cube*) is less than that for the first or for the second cube for the five lower age groups, but for the three higher age groups, i.e., 36, 40, and 52 weeks, the amount of regard remains the same as for the first and second cubes. This decrease in regard on the part of the lower age groups is for the most part due to the presence of the other cubes, one held in each of the infant's hands, and perhaps somewhat to the fact that this cube is the third of three similar objects presented in succession to the infant. We have no proof with which to support these statements in the case of the 16-weeks group, but in the case of the 20-weeks group the regard goes readily to the cubes and to the hands which hold these cubes (see Table 1). For example, we find that two of the infants, instead of looking first at the third cube when it is presented, look rather at the other cubes, that, in the case of four infants, the second regard is for the hands, and that this regard for the hands is the most important item from the point of view of duration for the second regard. The third regard, instead of going to the third cube is largely for the first and second cubes. Again, in the third cube situation the 24-weeks group shows a definite tendency to regard the first and second cubes; two of the infants prefer them for the first regard for 12.0 seconds as compared with ten infants who prefer the third cube for a group total of 30.0 seconds. For the second regard, six infants prefer the first or second cubes (32 seconds), the largest item for the second re-

gard, and the third regard is also generously given for the first or second cube. The first and second cubes, to a great degree, continue to attract the regard at 28 weeks and to a lesser extent at 32 weeks. At 36, 40, and 52 weeks the infants regard the third cube about as long as they regard the first and second cubes when they were first presented; for, while at this age infants continue to look at the cubes in the hand, their regard for these cubes is of very short duration (Table 1, *Duration of regard, Third cube*). The curve for the average duration of the regards follows pretty closely the curve of total duration of regard, except with a deviation at 24 weeks, at which age the presence of the cubes in the hands interferes to shorten the periods of regard for the third cube. This same explanation goes for the dip in the curve for first regard at 24 weeks, which in other respects corresponds closely with the curve for total regard.

In the first cube situation the 28-weeks group gives the longest single regard (15.0 seconds median) for the cube. The 24-weeks group follows with 10.0 seconds. The remaining groups are on equal terms with the exception of the 16-weeks group, whose longest single regard is but 3.25 seconds. In the second cube situation the 24-weeks group and the 28-weeks group lead in longest single regard with 10.0 seconds and 9.5 seconds, respectively. For the remaining groups the situation is about as described for the first cube situation. In the third cube situation the groups are closely bunched with respect to longest regard, with the exception of the 16-weeks group who again rank lowest. The standard deviation in all cases is fairly high.

ORDER OF REGARD

In the case of certain age groups the first three regards for objects about the infant appear to follow a certain order (Table 1). Beyond the third regard there is no order in the sequence of objects attended for any group (table showing this fact is not given). For the first cube situation the objects which the infant may regard are the cube, the infant's hands, the table top, the examiner, and the dome, which includes the light, screen, and other parts of the dome visible to the infant. For the second cube situation and for the third cube situation we have an additional item, the other cube (s), meaning the cube (s) held in the infant's hands during the presentation of the second and the third cubes, respectively.

If we are to generalize, we find that the 16-weeks infants first regard the presented third cube, then regard the table top or their hands, and, thirdly, regard the cube again, or the examiner. Although we recognize the general scattering of regard, this conclusion holds roughly for all three situations, because infants at this age appear to be very slightly influenced by the presence of the additional cubes.

Table 2 presents a summary of the objects of second and third regards for the several age groups in the first cube, the second cube, and the third cube situations. We omit the first regard, since it generally goes to the cube. The numerals in the first left-hand column indicate the age groups. Reading to the right, the three pairs of columns indicate the initials of the several objects of second regard and of third regard for the first

TABLE 2

SUMMARY OF OBJECTS OF SECOND AND THIRD REGARD FOR THE SEVERAL AGE GROUPS IN THE THREE CUBE SITUATIONS

The letters *C, D, E, H, O,* and *T* refer, respectively, to the cube, dome, examiner, hand, other cube, and table. When two or more items appear for an age group, the left-to-right order indicates their importance.

Age groups	First cube Second regard	First cube Third regard	Second cube Second regard	Second cube Third regard	Third cube Second regard	Third cube Third regard
20	E T D	C	E	C H D	H E	O E
24	E D	C	D O	C	O D	C E
28	D E	C	O D	C	O	C D
32	D	E C	O D	C	O D	C E
36	E D	C	O D	C	O D	C
40	D E	C	O D E	C	O E	C
52	E D	C	D	C	D	C

cube, second cube, and third cube situations, respectively. The letters *C, D, E, H, O,* and *T* refer, respectively, to the cube, dome, examiner, hand, other cube, and table. When two or more items appear for an age group in one column, the order left to right indicates their importance.

The outstanding feature of the regard sequence for all age groups is that when the first regard is for the presented cube, in spite of where the second regard goes, the third regard is most certain to be for the cube. In other words, the third regard returns to the object of the first regard. In the first cube situation, except for the 16-weeks group, the second regard is either for the examiner or for the dome. In the second cube situation, excepting the 16-weeks and 20-weeks groups, the second regard is either for the dome or the cube placed in the hand. In the third cube situation, if we except the two youngest groups, the second regard again

goes either to the cubes in the hand or to the dome. An interesting development is that in both the second and third cube situations the cubes held in the hand lead in attracting the second regard for practically all except the 52-weeks group. At 52 weeks the dome leads by far in gaining the second regard. In contrast to the older groups, the 16- and 20-weeks groups give much regard to the hands and the table top. They rub, scratch, and tap the table top with their fingers (see Table 22, also Table 4, *Total regard duration*). Preyer (46) says that infants from 17 weeks to 24 weeks are very attentive to their fingers. Up to 28 weeks the examiner finds difficulty in securing the infant's attention, and it often happens that when she secures the regard for the cube which she is presenting, the regard goes immediately to a cube already held in the hand. This occurrence naturally disturbs the order of the succeeding regards, for the evidence in Table I shows that often the second regard, instead of the first, is for the presented cube.

In a further analysis of specific infant behavior (see footnote 2, page 132), we have listed the objects of regard and the number of shifts in regard for these objects. In arranging these age groups with respect to the fewest number of shifts in regard, we have for the first cube situation the following order: 28-weeks, 32-weeks, 24-weeks, 40-weeks, 36-weeks, 16-weeks, 20-weeks, and 52-weeks. The order for the second cube situation is 28-weeks, 52-weeks, 32-weeks, 24-weeks, 36-weeks, 20-weeks, 40-weeks, and 16-weeks, and the order for the third cube situation is 32-weeks, 16-weeks, 28-weeks, 20-weeks, 40-weeks, 24-weeks, 52-weeks, and 36-

TABLE 3

NUMBER OF REGARDS WHICH INFANTS OF THE SEVERAL AGE GROUPS GIVE TO THE VARIOUS OBJECTS

Age	Cube	Other cubes	Hands	Table	Examiner	Dome	Total no. regards for all objects
16	70	9	21	30	30	23	183
20	74	20	20	16	31	27	188
24	84	30	10	9	18	24	175
28	71	27		1	8	28	135
32	69	23	1		20	36	149
36	97	43			16	40	196
40	87	33	2	3	28	34	187
52	91	11		4	19	66	191

weeks. If we consider the three situations as a whole (Table 3), the order is 28-weeks, 32-weeks, 24-weeks, 16-weeks, 40-weeks, 52-weeks, 20-weeks, and 36-weeks. The actual figures show that the 28-weeks groups and the 32-weeks group shift their regard for objects about them considerably less than do the other groups, and that the six other groups, the 36-weeks, the 52-weeks, the 20-weeks, the 40-weeks, the 16-weeks, and the 24-weeks groups, often shift their regard.

Table 3 indicates the total number of regards infants of the several age groups give each object. The several age groups are indicated in the first left-hand column, and the number of regards of each of the several age groups for the cube, other cube, hands, table, examiner, and dome appear in the six columns under these above-mentioned items. The extreme right-hand column indicates the total number of individual regards of each group for all objects.

TOTAL REGARD

In the first cube situation all groups are more con-

cerned with the cube than with any other one object; the 28-weeks group leads in this respect, the 24-weeks group ranks second, and the 36-, 40-, 20-, 52-, 32-, and 16-weeks groups follow in order (Table 4). In the second cube situation the groups arrange themselves in practically the same order as above with respect to the amount of regard for the cube. In the case of the third cube, while there are some shifts in this order of the groups, enough traces of the order remain so that the same arrangement of the age groups prevails with respect to the total duration of regard for all of the presented cubes in the three situations.

Table 4 shows the total time of regard by the infants of the different age groups for each of the several objects about them. The three situations are indicated at the top of Table 4, and under each situation are the columns of the objects within visual range of the infant. The age groups are in the extreme left column, while at the right of each age group are four cells which, reading down, indicate the total regard in seconds, the median, the standard deviation, and the number of infants involved, respectively, in computing the regard for the several objects. For example, in the first cube situation the total regard for the cube is 83.5 seconds, the median of which is 4.75 seconds, with a standard deviation of 5.4 seconds for 12 infants who actually regard the cube.

In all situations the 16- and 20-weeks groups manifest considerable interest in the hands and in the table top, for which the 24-weeks group shows little interest, and the others show practically no interest at all.

The two youngest groups again give more regard for

TABLE 4

Total Time of Regard by the Infants of the Different Age Groups for Each of the Several Objects, Together with Medians, Standard Deviations, and Number of Cases

Age		First cube					Second cube						Third cube					
		Cube	Hands	Table	Ex.	Dome	Cube	Other cubes	Hands	Table	Ex.	Dome	Cube	Other cubes	Hands	Table	Ex.	Dome
16	Total	83.5	31.0	44.0	46.5	34.0	69.0	25.0	34.5	24.0	34.5	55.5	52.5	24.0	32.0	24.5	39.0	28.5
	Med.	4.75	3.75	4.50	3.50	8.50	6.75	6.50	6.00	3.75	4.00	6.50	4.00	8.00	5.25	3.00	6.50	2.50
	S.D.	5.40	4.46	4.40	5.43	4.97	3.99	6.33	6.06	2.14	3.25	4.05	4.12	3.67	7.01	1.53	5.45	5.58
	Cases	12	6	9	8	5	12	3	4	6	7	7	12	3	4	8	5	5
20	Total	138.5	22.0	25.0	48.0	43.5	148.0	25.5	47.5	13.0	30.5	15.5	106.5	56.5	23.0	6.5	16.5	33.0
	Med.	9.25	5.00	3.00	3.00	4.75	11.50	6.25	6.25	2.50	2.50	2.50	6.75	6.00	3.00	3.25	2.00	7.00
	S.D.	4.72	2.81	4.51	6.40	4.05	5.52	3.42	3.33	2.09	5.23	2.12	6.73	2.67	3.82	1.25	0.87	3.15
	Cases	14	5	6	8	8	14	4	8	4	7	5	12	9	5	2	7	5
24	Total	187.5	12.5	9.5	24.0	24.0	171.0	34.5	11.5	18.5	10.5	14.0	117.5	101.5	2.5		14.5	24.0
	Med.	15.50	6.25	3.00	2.50	2.50	14.00	5.50	5.25	6.00	5.25	3.00	10.00	10.00	1.25		1.25	5.25
	S.D.	3.90					4.45	2.49	0.75	3.07	1.75	1.05	3.35	4.59	0.25		2.34	2.59
	Cases	13	2	3	7	8	13	7	2	3	2	5	13	11	2		6	4
28	Total	218.0		4.0	16.5	21.5	171.5	57.0			2.5	29.0	120.5	81.5				53.0
	Med.	18.00		4.00	4.50	4.00	16.00	6.75			1.25	4.25	8.50	9.50				9.75
	S.D.	3.99		0.00	4.26	1.69	6.33	4.62			0.75	2.29	3.99	4.00				5.48
	Cases	13		1	3	5	13	8			2	6	13	10				6
32	Total	122.5	2.0		36.5	79.0	121.0	40.0			20.5	58.5	94.5	55.0			14.0	36.5
	Med.	10.00	2.00		4.50	9.25	9.50	6.00			3.75	9.25	7.25	9.00			2.00	3.50
	S.D.	3.61	0.00		4.01	4.39	5.09	5.97			3.44	2.80	6.42	4.82			2.07	7.11
	Cases	12	1		7	10	12	5			4	6	10	6			5	5
36	Total	170.5			16.0	53.0	148.0	38.5			8.5	45.0	136.0	79.5			4.5	20.0
	Med.	14.00			2.25	6.25	11.75	4.00			2.25	4.50	12.00	7.50			1.50	4.50
	S.D.	3.86			2.10	2.47	3.84	2.86			0.75	3.51	2.42	2.68			0.41	1.20
	Cases	12			6	8	12	9			4	8	12	11			3	5
40	Total	147.5	2.0	5.5	15.5	69.5	137.5	51.0			19.0	29.5	144.0	54.0			27.5	14.5
	Med.	13.75	2.00	5.50	2.50	6.00	11.75	3.00			3.00	2.00	10.50	5.50			2.25	3.25
	S.D.	5.85	0.00	0.00	1.20	4.84	5.10	5.60			1.47	4.36	4.91	2.78			2.24	0.90
	Cases	12	1	1	7	10	12	9			6	7	12	11			8	4
52	Total	125.0		2.0	29.0	78.0	134.0	2.5			5.0	96.5	113.5	29.5		6.5	18.0	63.5
	Med.	10.75		2.00	3.00	5.75	11.25	1.25			1.50	10.00	8.50	4.50		3.25	4.75	5.25
	S.D.	4.02		0.00	1.76	4.81	5.75	0.25			0.29	4.83	3.36	3.50		1.25	1.56	2.99
	Cases	12		1	9	10	12	2			3	10	12	5		2	4	10

E than do the other groups, and, while the 40-weeks group look often at *E* (see Table 3), the individual regards for her are short. In passing, it is interesting to note that the 28-weeks group seldom regard *E*.

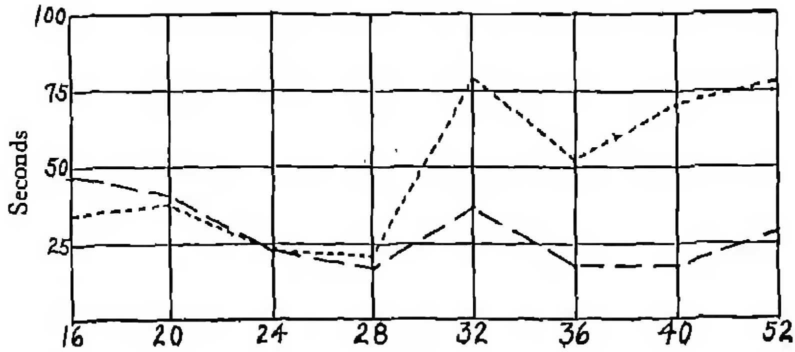
The surroundings (dome) particularly attract the oldest group. They regard the dome twice as long and twice as often as any other group regards it. This growth in amount of regard for this object is perhaps due to an increase of interest in their surroundings and greater sensitivity to the things about them. The 24-weeks group give little regard to the dome.

In the second and third situations the 24- and 28-weeks groups give more regard to the cubes held in the hands than do the other groups, while the 52-weeks infants scarcely notice these cubes.

The presented cube, for all groups in each of the situations, is the greatest magnet for drawing the regard. The amount of regard given the other objects, however, varies for the different groups. Neither the 16-weeks group nor the 20-weeks group favors any particular object, the 24-weeks group prefer the other cubes, the 28-weeks, 32-weeks, 36-weeks, and 40-weeks groups divide their preference between the other cubes and the dome, while the infants of the 52-weeks group clearly indicate their choice for the dome.

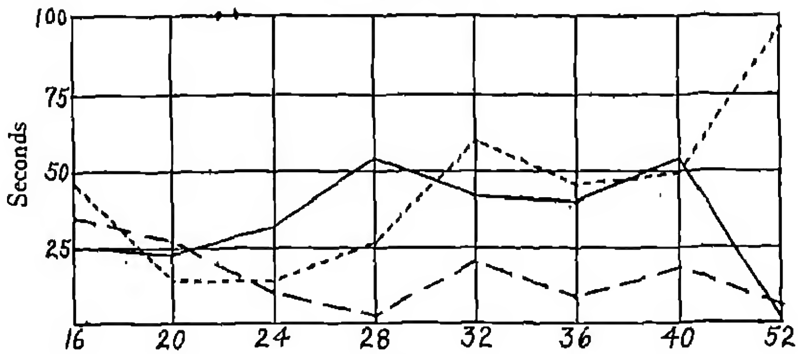
The three graphs of Figure 4 show the total time in seconds which infants of each age group consume in regarding (1) the cubes held in the hand, (2) the examiner, and (3) the surroundings for the first cube situation, the second cube situation, and the third cube situation, respectively, on the basis of 12 infants to each

First Cube



Age

Second Cube



Age

FIGURE 4

DURATION OF REGARD FOR THE CUBES HELD IN THE HAND, FOR THE EXAMINER, AND FOR THE SURROUNDINGS IN EACH OF THE THREE CUBE SITUATIONS

(12 infants in each group)

Cube in hand ————

Examiner — — — —

Surroundings - - - - - -

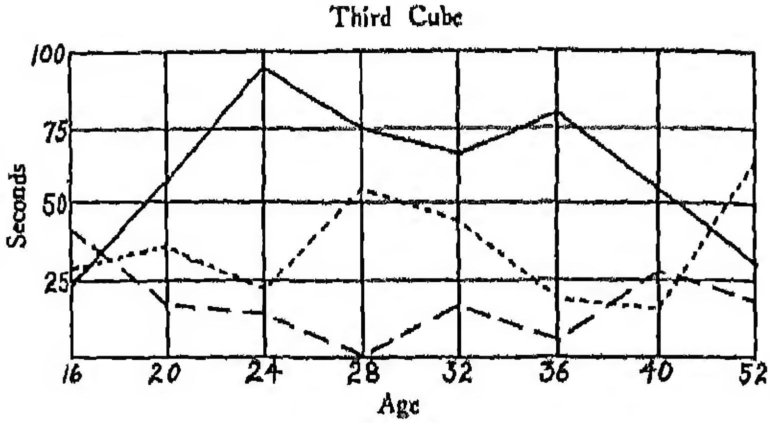


FIGURE 4 (*continued*)
DURATION OF REGARD FOR THE CUBES HELD IN THE HAND, FOR THE EXAMINER, AND FOR THE SURROUNDINGS IN EACH OF THE THREE CUBE SITUATIONS
(12 infants in each group)

Cube in hand ————
Examiner — — — —
Surrounding ------

group. The several age groups are indicated on the ordinates and the time is indicated on the abscissa of the three graphs.

The graph of the first cube situation in Figure 4 shows that the regard for *E* is not particularly outstanding at any age, but is greatest at 16 weeks. The regard for the surroundings assumes considerable importance for infants from 32 weeks to 52 weeks of age. In this situation there are no cubes in the infant's hands.

The graph of the second cube situation, Figure 4, reveals that while the regard for the examiner is greatest at 16 weeks none of the group regard her extensively. The regard for the surroundings assumes considerable

importance at 52 weeks and, in general, is greater for the 32-weeks, the 36-weeks, and the 40-weeks groups than it is for the lower age groups. The cube in the hand commands a considerable amount of regard from 28 weeks to 40 weeks, but at 52 weeks there is almost no regard for this cube.

The graph of the third cube situation, Figure 4, shows that, with the exception of the 16-weeks group, the amount of regard for the examiner is slight. The 52-weeks group regard the surroundings considerably, the 28-weeks and the 32-weeks groups also regard it to some extent, but the remaining age groups regard it only slightly. The cubes in the hand, to a very great extent, hold the regard of the 24-weeks group and, to a slightly less extent, the regard of the 36-, 28-, and 32-weeks group. The 16-weeks and the 52-weeks groups give little regard to the cubes in the hand.

If one considers these three situations as a whole, one finds that the regard for the examiner does not assume importance for any of the age groups, and that, at 28 weeks, infants scarcely regard the examiner. The regard for the surroundings is greatest for the four oldest age groups, and particularly so for the 52-weeks group. The 16-weeks and the 52-weeks groups give very little regard to the cubes held in the hand, but the 24-weeks, the 28-weeks, the 32-weeks, the 36-weeks, and the 40-weeks groups regard these cubes for a considerable time.

THE REGARD FOR THE CUBE AND THE EXPLICIT REACTIONS TO IT

In order to facilitate the study of the overt reactions

to the cube and their relation to the infant's regard for it we present the material in Table 5. This table summarizes for each of the three situations and for the total situation the number of times the infants of the several age groups regard the cube before they grasp it, the number of contacts with the cube, the number of grasps, the number of attempts to reach the cube, the number of failures to reach it, the duration in seconds of these failures, and the number of infants in each group who actually fail to touch the cube. The situations are listed in the first left-hand column, the numerals in the second column indicate the age groups, and the succeeding columns list the number of times that the several above-mentioned reactions occur for each age group. This table is based on the reactions of exactly 12 children for each group.

A review of Table 5 reveals the following facts. In the first cube situation the four older groups, ranging from 32 weeks to 52 weeks of age, give fewer regards to the cube before grasping it than do the four younger groups. Up to the age of 28 weeks, the number of grasps that infants make appears to increase with the age of the child. For example, there are no grasps at 16 weeks, two at 20 weeks, six at 24 weeks, and so on. The four older groups make fewer attempts to reach the cube than do the younger groups. There seems to be a contradiction of this point at 16 weeks, but when we realize that, for infants of this age, grasping the cube is quite out of the question and that all attempts to touch the cube are likely to be futile, we realize to a certain extent the occasion for the relatively few attempts by these infants to reach for the cube. With

the exception, again, of the 16-weeks group, the number of failures to touch the cube, with respect to the total number of attempts to reach it, decreases rather constantly with age. This decrease is particularly noticeable from the age of 20 weeks to 32 weeks. The

TABLE 5
REGARD FOR CUBE AND EXPLICIT REACTIONS TO IT
(12 infants in each group)

Situation	Age Group	No. regards to grasp	No. contacts	No. grasps	No. attempts to reach cube	No. failures to reach cube	Duration of failures (sec.)	No. infants actually failing
First cube	16	27	2	0	22	20	33.5	8
	20	27	7	2	40	33	71.0	13
	24	32	13	6	42	24	50.0	11
	28	25	7	15	37	13	21.5	6
	32	16	2	16	22	4	2.0	2
	36	18	10	14	29	7	9.0	2
	40	19	6	16	22	1	0.5	1
	52	20	0	21	24	3	8.5	2
Second cube	16	26	1	0	12	11	18.5	6
	20	29	10	2	39	27	60.5	13
	24	30	12	8	37	18	39.5	12
	28	24	14	7	32	11	9.5	6
	32	23	5	12	19	4	4.5	3
	36	19	11	15	29	3	5.0	2
	40	20	12	12	29	5	5.0	4
	52	22	4	16	21	1	1.0	1
Third cube	16	21	0	0	15	15	28.5	8
	20	18	5	1	33	27	40.0	10
	24	25	12	5	24	7	6.0	5
	28	25	18	6	34	11	15.0	7
	32	23	11	4	22	7	5.0	3
	36	29	25	14	45	6	5.0	5
	40	29	25	7	36	5	2.5	4
	52	28	14	8	28	6	3.5	4
Total	16	74	3	0	49	46	80.5	22
	20	74	22	5	112	87	171.5	36
	24	87	37	19	103	49	95.5	28
	28	74	39	28	103	35	46.0	19
	32	62	18	32	63	15	11.5	8
	36	66	46	43	103	16	19.0	9
	40	68	43	35	87	11	8.0	9
	52	70	18	45	73	10	13.0	7

amount of time consumed in these failures and the number of infants actually failing to touch the cube also follow this general rule.

In the second cube situation we find practically the same conditions, with respect to the infants' reactions to the cube, that hold in the case of the first cube situation.

The four older groups of infants regard the third cube oftener before they grasp it than they do the first cube. They make as many, and occasionally more, attempts to reach the third cube, and there is some irregularity in the order of the groups with respect to the number of failures to reach the cube, the time consumed in these failures, and the number of infants actually failing, as compared with the similar reactions in the first cube situation. We pause here to reflect that the third cube situation is a unique one for infants, because the introduction of three cubes within a child's range of prehension complicates the conditions so that his reactions to the presented cube in this situation are likely to differ greatly from his reactions to the presentation of the first cube. In other words, it is likely that the child believes that " 'two' birds in the hand are worth 'one' in the bush." If we consider the situations as a whole (Table 5), we find that the reactions of the several age groups closely parallel their reactions to the first cube; that is, as compared to the four younger age groups, the four older age groups regard the cube a slightly fewer number of times before they grasp it, the number of grasps increases gradually with age up to 36 weeks, and, in general, the number of attempts to

reach the cube, the number of failures to touch it, the duration of these failures, and the number of infants actually failing, are less for the four older age groups than for the younger age groups. In other words, there is for the four older age groups rather a marked improvement in the infant's ability to reach and grasp the cube.

Figure 5 shows the percentage of failures to touch the cube of the total number of attempts to reach it for each of the eight different age groups in the case of the first cube situation, and for all situations regarded as a whole.

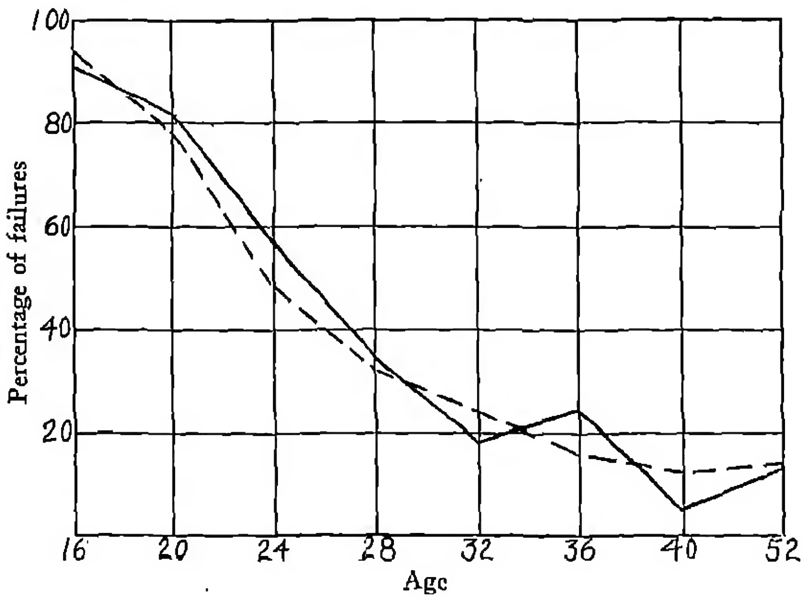


FIGURE 5
PERCENTAGE OF FAILURES IN ALL ATTEMPTS TO REACH THE CUBE

First Cube ————
All cubes — — — —

The eight age groups are indicated by the ordinates of the graph and the percentage of failures is measured by the abscissa. This figure demonstrates clearly the improvement in the accuracy of reaching for the cube by the infants with increase in age. At 16 weeks practically all infants fail in their efforts to touch the cube, and these failures become fewer and fewer until the infant is 40 weeks of age when the infants fail to touch the cube in only 12% of the total number of times they reach for it. This rule holds for the first cube and for all three cube situations when they are considered as a whole.

The Approach

This paper presents three situations, the one-cube, the two-cube, and the three-cube situations, and it is our purpose throughout to regard them as distinctly different, one from another. There are occasions, however, upon which we may combine certain of the results of the investigation of the three situations into one table or graph. It is our plan, therefore, in studying how infants reach for objects, to present first the data of the first situation and then the data of all situations taken as a whole.

We find it necessary to lay down certain premises in order to obtain the measures which are presented in Tables 6 and 7. For example, we determine the time up to the first approach by counting the number of motion-picture frames from the moment that the child first fixates the cube, as it appears in the examiner's hand, to the moment that the child begins the approach movement by either hand.

Table 6 lists the age groups in order in the first left-hand column. The median, the standard deviation, and the number of infants in each group who actually approach the cube are listed in order in each age group in the 16 columns of the numerous forms of reactions which are itemized at the top of the table. In the 9 columns on the right in the table which contain the data on the aim, form, and broad classification of the approach, we merely indicate the number of infants in each of the age groups who react in the manner indicated at the head of these columns.

Table 7 contains data essentially similar to that which we find in Table 6 with the exception of the omission of the aim, form, and kind of approach. The figures in the several cells of the table opposite the age groups are the averages of the medians of the numerous forms of reactions listed at the top of the columns for the three cube situations and are obtained from Table 6, and other tables not herein given.

In Tables 6 and 7 the medians for the time to the first approach and the time to the best approach for the age groups give the actual time in seconds from the beginning of the episode to the start of the approach. The first approach is not always the best approach, especially for the younger age groups. The best approach is that advance by the hand upon the cube which carries the hand nearest to the cube. The older infant usually follows the approach with a grasp, other infants succeed in touching the cube, and the very youngest infants usually miss it entirely. The *actual-approach time* is given in terms of the number of frames of motion film (1/16 sec.) from the start of the

approach to the moment of contact with the cube or, in case of an incomplete approach, to the moment the advance upon the cube ceases. The *approach length* is the shortest distance in inches, with reference to the tip of the forefinger, from the starting-point of the approach to the stopping-point. The *approach rate* is the speed of the advance in seconds and is obtained by dividing the approach length by actual approach time. The *number of changes in direction* is the number of lateral deviations of the hand during the approach. The *amount of digression* is obtained by drawing a straight line from the cube to the position of the forefinger tip at the start of the approach and measuring the greatest distance of forefinger deviation left to right of this line during the approach.

The *maximum height* is the greatest height above the table which the forefinger attains in the approach. We indicate the *stage* (see the four stages of approach, Table 8) at which the maximum height occurs. The *distance from cube* is the shortest distance from the cube to the forefinger at any point in the approach. The *progress to the cube* is the difference in inches, with reference to the forefinger tip, between the distance from the cube at the start of the approach and the distance from the cube at the end of the approach. *Stage reached* refers to the one of the four stages of the approach attained by the hand before the advance upon the cube ceases. The side camera gives us the *elbow-angle* both at the *start* and at the *end* of the approach and the *forward trunk and head displacements*. We obtained the figures for these items

TABLE 6
The Approach—First Cube

Age		Time to first approach (sec.)	Time to best approach (sec.)	Actual approach-time (frames)	Approach length (inches)	Approach rate (inches)	No. changes in direction	Amount of digression (inches)	Maximum height (inches)	Where maximum height occurs	Distance from cube (inches)	Progress to cube (inches)	Stage reached	Elbow angle (degrees)—start	Elbow angle (degrees)—end	Body displacements	Head displacements	Aim of approach: At cube	Aim of approach: At side	Aim of approach: Cuts in	Form of approach: Circuitous	Form of approach: Straight	Form of approach: Backhand	Broad class: Bilateral	Broad class: Partial bilateral	Broad class: Unilateral
	Med.	5.0	9.0	21.0	1.5	1.35	0-3	2.75	1.25	1.0	4.5	0.5	2.0	85.0	115.0	0.0	25.0									
16	*S.D.*	4.91	4.37	28.9	1.14	2.16	1.0	1.11	1.32	0.4	1.2	1.1	1.0	28.2	20.6	3.5	7.9									
	No. cases	8	8	8	12	8	8	8	8	6	8	12	12	8	8	8	8	1		7	5		2	1	2	5
	Med.	2.0	11.0	46.0	3.75	1.1	0-7	2.5	2.0	1.0	4.0	2.5	4.0	110.0	120.0	0.0	25.0									
20	*S.D.*	5.62	6.82	24.5	2.02	1.31	2.5	2.05	1.75	1.3	1.8	1.5	1.0	44.4	36.8	13.6	9.1									
	No. cases	13	13	13	14	13	13	13	13	13	13	13	13	13	13	13	13	3		10	10	3		3	1	9
	Med.	1.0	2.0	19.0	5.0	2.6	0-4	2.0	2.5	1.0	1.0	4.0	4.0	150.0	150.0	10.0	30.0									
24	*S.D.*	3.9	4.7	26.0	2.6	2.9	1.3	0.5	2.5	1.2	2.8	3.1	1.2	47.5	11.2	8.9	8.1									
	No. cases	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	6	2	3	9	2		8	1	5
	Med.	2.0	2.0	27.0	6.5	3.7	0-3	1.5	3.5	2.0	0.0	5.0	4.0	120.0	160.0	10.0	25.0									
28	*S.D.*	2.6	2.10	30.0	3.2	3.8	1.0	1.3	1.7	0.6	0.9	3.1	0.0	32.6	22.5	8.9	6.8									
	No. cases	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	5	4	1	10	2		5	1	7
	Med.	1.0	1.0	16.0	5.8	7.4	0-3	1.5	3.0	2.0	0.0	6.0	4.0	115.0	160.0	20.0	30.0									
32	*S.D.*	3.4	6.1	6.6	3.0	6.5	1.1	0.7	2.1	0.8	1.3	3.1	0.0	35.7	14.8	9.5	3.4									
	No. cases	11	11	11	11	11	11	11	11	11	11	11	11	10	11	11	11		11		11			6		6
	Med.	1.0	1.0	19.0	6.5	5.1	0-2	2.0	3.0	2.0	0.0	5.0	4.0	100.0	150.0	15.0	30.0									
36	*S.D.*	0.8	0.8	6.1	2.8	3.5	0.8	1.0	1.6	0.7	0.0	2.8	0.0	22.8	16.2	1.0	0.6									
	No. cases	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	2	9		4	7		4		7
	Med.	2.0	2.0	16.5	4.8	5.3	0-1	1.0	3.0	2.0	0.0	3.3	4.0	115.0	160.0	20.0	30.0									
40	*S.D.*	5.7	5.7	4.2	2.6	1.8	0.5	1.3	1.3	0.0	0.4	2.5	0.0	27.5	12.3	6.5	10.5									
	No. cases	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	1	11		3	9				12
	Med.	1.5	1.5	23.0	3.0	1.3	0-1	1.0	2.0	2.0	0.0	3.0	4.0	130.0	150.0	20.0	25.0									
52	*S.D.*	2.6	2.6	31.8	3.3	3.6	0.5	0.8	1.10	0.0	0.9	2.8	0.0	21.3	17.9	6.6	5.8									
	No. cases	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	1	9	1	4	7		2		9

by applying a protractor to the ground-glass image. The relation of the line of the back of the infant to a perpendicular to the table top gives the body displacement and the angle of the face (the forehead-to-chin line) to this perpendicular gives the head displacement.

Table 8 shows for each of the several age groups the manner (1) in which infants aim their forearm during the approach, (2) the form of the approach, and (3) whether they use one or two hands to reach the cube.

TABLE 7

THE APPROACH

The figures are the averages of the medians for the three cube situations.

	Age in weeks							
Measures	16	20	24	28	32	36	40	52
Time to first approach (sec.)	3.3	2.5	3.6	2.1	1.5	1.9	2.1	2.1
Time to best approach (sec.)	4.7	6.8	4.6	4.1	1.5	2.5	3.1	6.1
Actual approach-time (frames)	23.8	39.7	19.6	21.3	16.6	16.8	17.1	18.0
Approach length (inches)	1.5	3.7	3.6	5.6	5.6	5.8	5.4	5.2
Approach rate (inches)	1.3	1.1	2.3	4.2	5.8	5.7	5.0	5.0
No. changes in direction	0-11	0-7	0-7	0-4	0-3	0-3	0-2	0-1
Amount of digression (inches)	3.1	3.2	2.1	1.8	2.0	2.1	1.5	1.3
Maximal height (inches)	1.9	2.7	2.3	2.8	3.0	2.9	2.9	2.1
Distance from cube (inches)	4.6	3.4	1.8	1.0	0.0	0.0	0.0	0.0
Progress to cube (inches)	0.7	2.4	3.3	4.8	5.1	4.8	4.2	4.4
Elbow-angle (degrees)—start	81.7	90.0	130.0	100.0	100.0	86.0	93.0	118.0
Elbow-angle (degrees)—end	100.0	127.0	151.0	160.0	160.0	151.0	158.0	156.0
Body displacements	0.0	4.2	10.0	6.0	20.0	17.5	19.1	18.0
Head displacements	25.8	27.5	27.5	25.0	29.1	30.8	30.0	26.0

TABLE 8

AIM, FORM, AND CLASSIFICATION OF APPROACH

The figures refer to the number of infants displaying the behavior indicated.

	Age in weeks							
	16	20	24	28	32	36	40	52
Aim of approach:								
At cube	2	10	15	14	7	8	4	8
At side	0	0	4	8	17	18	20	17
Cuts in	11	23	8	3	0	1	1	1
Form of approach:								
Circuitous	11	27	22	18	22	12	10	7
Straight	1	5	3	8	2	15	15	19
Backhand	3	3	3	1	0	1	0	0
Broad classification								
Bilateral	1	11	13	7	6	5	1	4
Partial-bilateral	2	2	2	1	0	0	0	1
Unilateral	12	20	16	20	19	22	24	21

The age groups are listed across the top, and the remaining cells of the table refer to the number of infants of each group. While the table includes all three situations, it lists only those approaches in which the hand is empty. A number of infants are omitted under the *Aim of approach* because the exact aim was indeterminable.

The *aim of the approach* is a significant item in infant growth (see Tables 6 and 8). The aim of the hand in very young infants can scarcely be determined, for the hand usually starts from any point on the table and swings out or in, or both out and in, but is certain to cut across the table top short of the cube. At a later age the aim is directed straight at the cube. The entire forearm and hand point at the cube, with the medius finger middlemost. Then, at a still later age, the forefinger

takes the lead in the approach by aiming above the top of the cube or its near-lateral face.

We recognize three forms of approach, (*a*) the *backhand approach,* in which the hand sweeps outward and forward toward the cube in curvilinear manner, with the ulnar edge of the hand leading, (*b*) the *circuitous approach,* in which the hand, in advancing, moves outward laterally during the first part of the approach, and inward toward the midline of the table during the latter part of the approach, thus describing an arc, and (*c*) the *straight approach,* the customary form of an approach for the oldest infants. In this approach, the path of the forefinger, as seen from above, approximates a straight line. The backhand and circuitous approaches of young infants resolve into the straight approaches of the older infants by a gradual straightening (shortening) of the line of advance upon the cube. At 36 weeks and at 40 weeks we find some excellent examples of immature straight forms of approach. The hands of some of these infants start straight for the cube but waver from left to right, or right to left, or in both directions, and have to be brought back into line with the cube; hence what starts as a straight approach becomes a sinuous approach. Straightening the course of the approach illustrates the principle of economy in time, space, and effort—the elimination of useless movements.

The *broad classification* simply indicates whether the approach is entirely *unilateral,* wholly *bilateral,* or *partially bilateral,* wherein one hand advances to assist the other.

Table 6 shows that for all infants, except those of the 16-weeks group, who in 11 instances attempt no approach, there is an immediate prehensory reaction to the first cube. Some groups, 24-, 32-, 36-, and 52-weeks, start for the cube before it is placed in position. The first approach for the five older groups, which begins within two seconds of the start of the situation, is usually their best approach, but for the three younger groups the first approach, which starts at five seconds, two seconds, and one second for the 16-weeks, 20-weeks, and the 24-weeks groups, respectively, is seldom the best approach. The best approach at 16 weeks occurs at nine seconds, and the best approach at 20 weeks occurs at eleven seconds. Note the time to the first and to the best approach for these groups. There is little consistency in the gain in actual approach-time with advance in age, and the amount of deviation within the groups is considerable, except for three groups, as the *S.D.*'s indicate. The approach-time for all groups, with the exception of the 16- and 20-weeks infants, who have more incomplete approaches than have the other infants, ranges from 1.0 second to about 1.5 seconds (16 frames to 27 frames). The short approaches by the 16-weeks infants last for 1.25 seconds (21 frames), and the awkward reaching at 20 weeks continues for 3.0 seconds (48 frames). Again we find a high variability within the individual groups. Watson (62) reports that reaching at 21 weeks (5 months) requires 3.0 seconds.

We might have adopted the plan of starting all situations by placing the infant's hand at predetermined

points on the table or at his sides were we certain that such demands on the infant would not interfere with or hamper his characteristic reaction to the cube.

The 28-weeks and 36-weeks groups extend the hands farther to get the cube than do the other groups, although the 32-, 24-, and 40-weeks groups are closely bunched behind them (see Table 6). The length of the approach depends largely on the position of the hand relative to the cube at the start of the approach. The 24-, 28-, 32-, 36-, and 40-weeks groups start with their hands well back at the near edge of the table, while the 52-weeks group usually have their hands well out on the table. The infants of the latter group, of course, have the advantage of 12 weeks of growth over the next oldest group and have correspondingly longer bodies and arms. The 16- and 20-weeks groups seldom reach beyond the *N.M.* point on the table—the nearer position of the cube. As a matter of fact, 19 approaches at 16 weeks and 14 approaches at 20 weeks fall short of the cube. With the exception of the 16-weeks infants, the length of the approach for all groups is from 3.0 to 6.5 inches. The 32-weeks group excels in rate of approach, with the 40- and 36-weeks groups next in order. The 52-weeks group ranks low in this respect, because (*a*) their short approach precludes speed, (*b*) two of the infants complete their approach without visual aid, which consequently retards their rate of movement, and (*c*) they are more deliberate about the placement of digits previous to grasp (see Table 17). We expect the low rate of movement for the three youngest age groups because of the very angular or very cir-

cuitous forms of approach displayed at this age. Instead of giving the median for the number of changes in the direction of the approach, we present the range, although the standard deviation is derived from the mode. The results conform with what we expect to find in directness of approach. The approach of the 20-weeks group is least direct, then follow in order the older age groups. The steady decrease in the standard deviations for the several groups confirms the fact that the older groups gradually improve the direction of advance upon the cube. The low state of activity toward the cube explains the small range exhibited by the 16-weeks group. The amount of digression from a straight approach appears to decrease steadily with age with the exception of the slight increase at 36 weeks. The maximal height of the approach increases gradually from 1.5 inches at 16 weeks to 3.5 inches at 28 weeks and then diminishes to 2.0 inches at 52 weeks. It is likely that measurements made with reference to some other point on the hand, other than the forefinger tip, will yield results different than those of our table.

The stage in the approach at which maximal height occurs well illustrates an outstanding difference between the types of approach by younger and older infants. Younger infants, in raising the hand for an approach, tend to lift the hand to the highest point immediately and frequently abduct the upper arm fairly high before they get well started forward, while older infants continue to elevate the hand on an acute angle with the table top until the hand is well out toward the cube.

We obtain the *distance from the cube* by measuring the distance from the *S.M.* position minus one-half the width of the cube to the nearest point obtained by the forefinger; hence, some of the infants may secure the cube at the *N.M.* position and still be remote from the cube in the *S.M.* position. The results show that the 16-weeks group and the 20-weeks group get no nearer the cube than 4.5 inches and 4.0 inches, respectively, that the 24-weeks group are but 1.0 inch from the cube, and that all the remaining groups succeed in at least touching the cube.

Progress to the cube depends largely on the distance of the hand from the cube at the start of the approach. The gain is to be accepted only as a general indication of the ability of the groups to reach the cube. The falling-off from the 32-weeks group to the 52-weeks group is due largely to the fact that the infants of these groups were closer to the cube at the initiation of the approach.

We made reference above to the four stages in the complete approach, which later we shall discuss at length. Suffice it to say that no 16-weeks infant accomplishes a complete approach to the cube,[8] that most of the 20-weeks infants are likely, sometime during the situation, to complete an approach, and that the remaining groups usually complete the approach to the cube. The 16-weeks infants start for the cube, but few of them succeed in diminishing the distance from the hand to the cube by more than one-half.

[8]The three infants of this age who touch the cube accomplish the contact on a backhand sweep which we regard as the first two stages of the incompleted circuitous approach.

The only noteworthy feature of elbow-angle, as shown in Table 6, is the little change in elbow-angle of the 16- and 20-weeks infants at the start and end of the approach. The 16-weeks and the 20-weeks infants seldom extend their arms fully in reaching, and the hand does not move freely at the end of a guiding forearm. The degree of flexibility of the arm appears to correspond closely with gain in independence of forefinger and thumb. We attempted to rate infants with respect to wrist and elbow flexibility, noting particularly the ease with which they approached and retrieved the cube, but decided that our knowledge of the age of the infants prejudiced the results. However, there can be no doubt that wrist and elbow flexibility increase steadily with age.

We do not take too seriously the figures on body displacement, although the fact is that older infants do lean farther forward in reaching than do younger ones. We recall that the younger ones in this experiment are placed in a Morris chair with a belt about them, and, while the belt is not too tight, it probably does interfere slightly with leaning. The extent to which infants incline their hands in reaching carries with it no age significance, the younger infants lower their heads about as far as do the older ones. The difference between the two younger age groups and the other groups lies in the fact that the former incline only the head during the approach, while the latter incline both body and head as a unit. At all ages, when one hand reaches for the cube, the infant's body usually leans slightly toward the opposite side.

The figures on the aim of the approach (Table 6) disclose some interesting facts. At 16 and 20 weeks, one cannot always determine the exact aim of the approach, for the hand cuts in short of the cube in a sweeping motion in which the intention is to corral the cube toward the chest. At 24 and at 28 weeks the approach shows the forearm and hand pointing paw-like directly at the cube with the midfinger above the center of the cube. Three of the 20-weeks group direct their aim in this manner. At 32 weeks there is an abrupt change in the aim of the approach. The infants now so direct the approach toward or above the near-lateral surface of the cube that the forefinger will pass diagonally over the cube on a line with its near vertical edge. This approach favors the placement of the first two fingers on the far face of the cube in opposition to the thumb on the near face. The 36-, 40-, and 52-weeks groups direct their approach similar to that of the 32-weeks group.

Of the three forms of approach, the circuitous is the most common form, the backhand appears infrequently, and the straight is the ultimate form of approach (see Figures 1 and 2). However, there are a number of approaches which begin as backhand and later resolve themselves into either the circuitous or the straight approach and are, therefore, classified under the latter categories. The 16-, 20-, 24-, 28-, and 32-weeks groups use the circuitous form of approach almost entirely. The 36-, 40-, and 52-weeks groups use largely the straight approach.

Figure 6 shows the route of the forefinger (*A*) of a 20-weeks infant, (*B*) of a 28-weeks infant, (*C*) of a 36-

weeks infant, and (*D*) of a 52-weeks infant in reaching for a cube. These routes are plotted from the individual frames of the motion picture from which the four stages of the approach which are shown in Figures 1 and 2 are taken. The four overhead views show the middle part of the table top, drawn to scale. In each

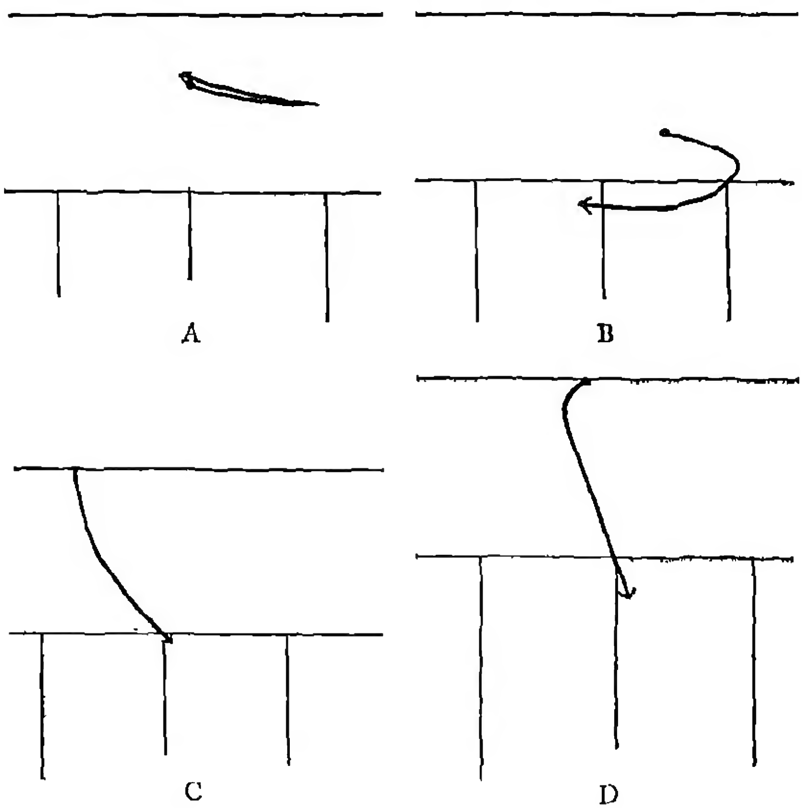


FIGURE 6
FORMS OF APPROACH
A. Route of the forefinger of a 20-weeks infant. B. Route of the forefinger of a 28-weeks infant. C. Route of the forefinger of a 36-weeks infant. D. Route of the forefinger of a 52-weeks infant.

view the top horizontal line represents the table edge which is nearest the infant and the remaining horizontal and vertical lines represent the lines on the table top. The angular line with the arrow-head (View A) indicates that the 20-weeks infant makes an angular circuitous approach. The curved line of View B shows that the route of the approach by the 28-weeks infant is very circuitous. The slightly curved line of View C shows that the route of the approach of the 36-weeks infant is only slightly circuitous, and the straight line of View D, with the slight crook at its origin, shows that the route of the approach of the 52-weeks infant is straight. The arrowheads indicate the direction in which the hand moves on the approach.

The arm and hand movements of young infants (16 and 20 weeks) consist largely of in-and-out lateral sweeps above or on the table, in which the shoulder serves largely as the source of action with very little elbow flexion or extension (62) to change its course or range of action, and with the hands exhibiting little of the independence of action so characteristic of the older infant. These rather angular zigzag movements (Figures 1A and 6A) of this age have genetic significance, for they round out into the very circuitous movements (Figures 1B and 6B) which characterize the corralling approach of the 24-weeks infant in whom shoulder action still strongly predominates. The latter form of approach is a typical corralling motion by which the infant draws the cube toward him on the table before he succeeds in gripping it. As the age of infants increases, this very circuitous approach then becomes less

corralling in nature and more like directed reaching until, at 32 weeks, the route of the approach is only slightly circuitous as in Figures 2A and 6C. In the last stage of its development the circuitous approach straightens out, as demonstrated in Figures 2B and 6D.

View A of Figure 6, which gives the route of the approach by the left hand of a 20-weeks infant, shows that this hand begins its approach to the cube from the midline of the table. The hand then sweeps out laterally on a slight curve until it reaches a point five inches to the left of the midline, and then sweeps back toward the midline, and finally comes to a rest at a point adjacent to the starting position. If we consider this approach in connection with the angular circuitous slide approach of Figure 1A, which is another representation of the same approach, we find that in the first stage of the approach the infant rotates his hand on the table slightly outward as he starts for the cube which is held in the examiner's hand. The infant then rotates his hand to a palm-in position as he sweeps it to the left to its extreme lateral position where it remains for 5.0 seconds in the second stage of the approach. The infant now slowly pronates the hand and begins to sweep it inward on the table (see third stage of approach) until the hand completes its approach three inches short of the cube (see fourth stage), when the regard shifts from the cube to the hand. This approach began before the cube was placed at the *N.M.* position and required fully 7.0 seconds for its completion. The shift of regard from the cube to the hand is typical of infants of this age.

A consideration of View B, Figure 6, in connection with the very circuitous loop approach of Figure 1B (the same approach), shows that in the first stage the infant raises his left hand three inches to free it from the table, after which he moves the hand out to the left and at the same time extends it forward where we find it in the second stage. The infant then continues to project the hand forward in curvilinear manner and also sweeps it medianward in a corralling type of motion, illustrated in the third stage, until, in the last part of the approach, the hand is slightly retracted as it sweeps above the cube. In this approach the infant fully extends the elbow as the hand sweeps out to its extreme lateral position in the second stage and readily flexes as the hand continues its approach. The right hand moves inward toward the median line in a corralling manner simultaneously with the inward sweep of the left hand.

A comparison of the two forms of approach illustrated in Figure 1 demonstrates clearly that flexibility of elbow is greater for the 28-weeks infant than for the 20-weeks infant.

If we combine View C of Figure 6 with the slightly circuitous planing approach of Figure 2A (another representation of the approach shown in View C), we find that this infant of 40 weeks first raises his right hand from the table edge while he frees the elbow from the trunk (see first stage of approach). He then projects the hand quickly forward in a slightly curved line as he raises the hand higher with a simultaneous lateral movement of the elbow, an action which tends

to point the forefinger in the direction of the cube (see second stage of approach). At this point the hand is tilted slightly upward, but as the infant continues the approach he begins to lower the hand, to tilt it downward, and to carry it medianward so that the first two fingers point directly above the top of the cube, as in the second stage. During this action the forearm is carried medianward. During the last part of the approach the infant continues to lower the hand until the first two fingers so pass over the cube that the thumb may be brought against the near surface of the cube.

A consideration of View D of Figure 6, in connection with the straight planing approach of Figure 2B, two views of the same approach, shows that this 52-weeks infant, after an initial orientation, thrusts the hand in a straight line for the cube. The infant raises his elbow from his side and his hand from the table in such a manner that his forefinger is at once pointed above the cube. The infant quickly accelerates the advance as he continues to raise the hand and tilt it slightly upward until he reaches the second stage. He then continues the advance without any loss of speed, and gradually tilts the hand horizontally, as in the third stage. Finally he tilts the hand slightly downward so that the forefinger passes immediately above the upper surface of the cube to bring the thumb against the near surface.

Very young infants usually carry objects immediately to the mouth, while older ones manipulate and finger the cube (see Table 21 under *Both hands*, *Puts down*, *Picks up*, and *Fingers cube*, also Table 22 in columns

Matches cubes and *Exchanges cube*). The high sensitivity of the lips undoubtedly influences the early hand-to-mouth activity, because the lips not only serve in the acquisition of food by sucking but also assist in the gaining of impressions of form, size, and other tactile data. With the older infants it is likely that as visual acuity and sensitivity of the finger-tips increase, the hand-to-mouth reactions weaken gradually, because of the failure of the lips to add further to impressions obtained by the digits and eyes. We believe that this difference in the reactions to objects by the younger and older infants accounts in part for the difference in the forms of approach of infants. The corralling or scooping approach of the young infant is but the first act in drawing the object in toward the mouth, while the more direct reaching of the older infants indicates that the object will be fully appreciated by hand manipulation.

It is not always easy to distinguish the straight approach from the slightly circuitous approach. We classify as slightly circuitous those approaches in which the forefinger fails to point definitely at the cube throughout the approach but swings out slightly laterally during the first or second stage of reaching. We classify as straight the approaches in which the forefinger points at the cube throughout the course of the approach.

The 16- and 20-weeks groups use principally the unilateral approach. One hand rests on the table as though partly to support the body, which for these two groups sags laterally, while the other hand advances

upon the cube. At these ages there is little coordination of the two hands such as we find at 28, 32, and 36 weeks, where the cube is readily shifted by the infants from one hand to the other (see Table 22, *Exchanges cube*). The 24-, 28-, and 32-weeks groups manifest rather strong bilateral tendencies in reaching and grasping. For these groups the second hand often accompanies the approach-hand to render assistance in corralling or in grasping the cube. At 36 weeks we find the unilateral approach again predominating, and at 40 and 52 weeks it is practically the only form of approach used.

An examination of Table 7 reveals that the four older groups of children, ranging from 32 weeks to 52 weeks, react more quickly to the presented cubes of the three situations, not only with respect to the time they first reach for the cube, but also with respect to the time of the best approach and the time required to complete the approach. There is one outstanding exception to this statement, and that is the time (6.1 seconds) to the best approach for the 52-weeks group. The slow reactions to the second and third cubes accounts for this high figure, because the time to the best approach in the first cube situation is only 1.5 seconds (see Table 6). The slow reactions to the second and third cubes is due, in part at least, to the infants' deliberateness in reaching for the cube, because they already hold one or two cubes.

Table 7 also shows that infants from 16 weeks to 24 weeks reach less than four inches to secure the cubes, while infants from 28 weeks to 52 weeks reach more

than five inches. The speed at which infants reach for all cubes (*approach rate*) increases gradually with age up to 32 weeks, after which the speed remains fairly constant. The number of corrections (*number changes in direction*) which infants make in reaching for the cube decreases in range directly with increase in age from 16 weeks to 52 weeks, and the amount of digression from the line representing a straight approach decreases somewhat irregularly from 20 weeks to 52 weeks. The maximum height of approach (with the exception of the 16-weeks group who do not complete the approaches) is least for the 52-weeks group, who resort principally to the planing type of reaching. The distance from the hand to the cube at the completion of the approach is greatest at 16 weeks (4.6 inches) and decreases rapidly to zero at 32 weeks. All infants from 32 weeks to 52 weeks of age reach the cube. The progress toward the cube during the approach increases from 16 weeks to 28 weeks and then remains fairly constant for the older age groups. There is no uniformity as to the amount of elbow extension which infants of the several age groups display at the start of the approach, but the amount of elbow extension at the end of the approach increases from 16 weeks to 28 weeks and then remains constant for the remaining age groups. This gain in extension of the elbow with increase in age is some indication of the greater flexibility of this joint in infants of 28 weeks and over. There is very little forward trunk displacement in infants ranging from 16 to 28 weeks, who are belted into their chairs, but infants from 32 to 52 weeks lean forward

about 20° from the vertical in reaching for the cube. Forward head displacement is practically the same for all groups.

The figures under *Aim of approach* (Table 8) reveal, as does Table 6, (*a*) that most of the infants of the 16-weeks and 20-weeks groups, several of the 24-weeks group, and very few of the 28-weeks group cut in short of the cube, (*b*) that, while a number of infants of each of the groups aim directly at the cube, this type of aiming is most characteristic of the 24-weeks and 28-

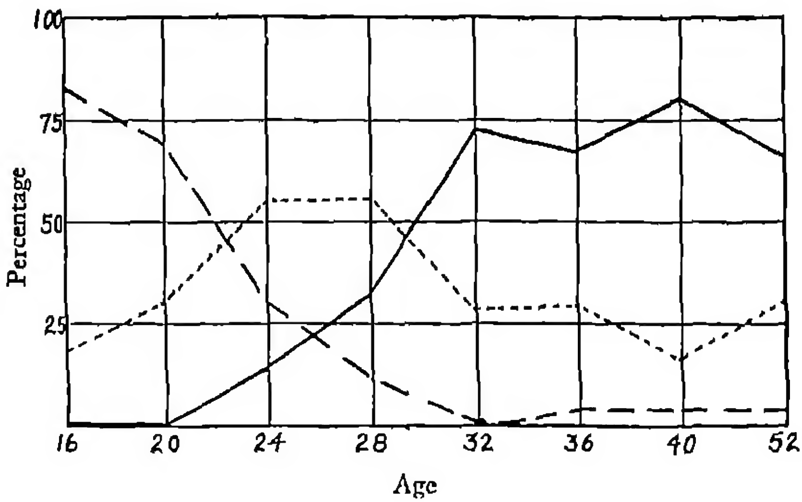


FIGURE 7

Percentage of Approaches (by the Empty Hand Only) in Which the Forearm Aims at the Cube, at the Side of the Cube, and Short of the Cube (Cuts in)

This figure also shows the relative amount of losses and gains in the types of aims for increase in age of the infants.

At side ————

Cuts in — — — —

At cube - - - - - - -

weeks infants, and (*c*) that, in general, the number of infants who aim at the side of the cube increases with the age of the infants.

Figure 7 shows relatively to what extent the several age groups resort to "cutting in," aiming fully at the cube and aiming at the side of the cube, by the forearm in reaching for the cube. The graph also shows the relative amount of losses and gains in the types of aims for increase in age of the infants. The age groups are indicated on the eight ordinates and the amount of the three types of aims used are shown in percentages on the abscissa of the graph. The graph includes approaches by the empty hand only.

Figure 7 illustrates the changes in the manner in which infants direct their forearms in reaching. Note the rapid decline in the *cuts-in* curve from 16 weeks to 32 weeks, the rise and subsequent decline of the *at cube* curve from 16 weeks to 32 weeks, and, finally, the rise of the *at side* curve from 20 weeks to 32 weeks. In conclusion, then, we may say that "cutting in" approaches predominate at 16 weeks and 20 weeks, that aiming "at the cube" appears oftenest at 24 weeks and 28 weeks, and that aiming "at the side" of the cube prevails over other forms of directing the forearm on the approach at 32 weeks, 36 weeks, 40 weeks, and 52 weeks.

The backhand approach (Table 8), which is usually only the first two stages of an incompleted circuitous approach, occurs generally, though infrequently, at 16 weeks, 20 weeks, and 24 weeks. The curve of the backhand approach shows that this form

of reaching at no age assumes any importance in prehension.

The Vertical Profile of the Approach

When one views laterally the reaching reactions of infants as they raise their hands, one notices that the route described by the hand of the older infant differs in profile from the route of the approach of the younger infant. The height to which infants raise their hands, as compared to their actual forward thrust in reaching, is greater for the younger infants than for the older infants. In addition, the younger infants raise, project, and lower the hand in a manner which shows that the path of the hand is an arc of small diameter, while the older infants project the hand forward toward the cube on a broad low arc which just skims the top surface of the cube. We call the arched approach of the younger infants a "loop," and the flat arc approach of the older infants "planing." In the latter case the hand "planes" in much the same manner in which an aeroplane moves when it "takes off," soars, and "lands."

For the 20-weeks and 24-weeks groups the acts of reaching, such as raising the hand, projecting it forward, and lowering it, appear almost as individual acts of a series of movements. At 40 weeks and 52 weeks, infants incorporate these three acts into a single fluent thrust. The rate at which the younger infants approach the cube is much slower than the rate at which the older infants reach for the cube (see Table 7, *Approach rate*). The younger infant appears to raise his hand and then direct its course toward the cube, while the

older infant, in raising his hand, simultaneously directs its course toward the cube, so that there is little loss in time or space. The completion of the loop is characterized by a sort of pawing or corralling motion so that the hand, instead of advancing forward, is pulled back as it nears the table top. Hence the loop approach, when it is successful, usually results in drawing in the cube for an inch or two before it is firmly grasped. At the end of the planing approach the hand no longer has the pawing characteristic but soars over the cube and is still moving forward as it settles upon the cube.

Naturally, infants do not always raise the hand from the table in reaching for objects, hence, when they slide their hand along the table top, we call this type of approach a "slide." Often an infant starts out with one type of approach and finishes with a different type. For this reason we find it necessary to introduce the loop-slide, and the slide-plane, and the loop-plane.

The loop-slide approach, which is usually quite marked at 24 weeks and at 28 weeks, is a combination of the loop and the slide. In this approach the infant usually misjudges the distance or the direction of the cube. The loop often occurs first, and, if the hand falls short of the cube upon being lowered to the table, the infant pushes the hand along the table top to complete the approach. It sometimes happens that this form of approach starts as a slide and ends as a loop.

The plane-slide approach differs from the loop-slide approach only in that the short planing movement occurs in place of the loop. The plane-loop approach closely resembles the planing approach but dif-

fers from it in that the hand is either raised too high or the approach ends with a pawing movement.

Table 9, indicates the number of each of these six profile types of approaches that occur for each age group. The loop approach occurs oftenest at 16 and at 20 weeks, frequently at 24 weeks, 28 weeks, and 32 weeks, infrequently at 36 weeks, and rarely occurs at 40 weeks and 52 weeks. The slide approach occurs frequently from 16 weeks to 32 weeks and very infrequently for the older age groups. At 24, 28, and 32 weeks we find that a slow transformation occurs in the vertical profiles. The mixed forms of approach, such as the loop-slide, appear in great numbers, and plane-loop and planing approaches begin to appear, all of which indicates a step forward in development. At these ages one may, however, expect any form of approach. At 36 weeks all approaches, with the excep-

TABLE 9

NUMBER OF INFANTS IN EACH AGE GROUP USING THE VARIOUS TYPES OF REACHING PROFILE

When the path of the hand in reaching, as seen from one side of the infant, describes an arc of small diameter, we call this type of reaching a *loop* approach. When the path of the hand resembles a broad arc of large diameter, we have a *planing* approach. When the hand simply slides out on the table, we have a *slide* approach. Combinations of these types form the *loop-slide*, the *slide-plane*, and the *loop-plane* approaches.

	Age in weeks							
Type of approach	16	20	24	28	32	36	40	52
Loop	14	19	9	9	8	6	1	
Loop-slide		3	8	9	3			
Slide	9	13	15	12	11	1	3	
Slide-plane			2	2	1	1	1	5
Loop-plane			2	2	4	5	1	3
Plane		1		5	5	22	30	26

tion of the planing type, drop out. The planing approach does not make its appearance to any extent until 28 weeks and then the number of these approaches increases rapidly after 32 weeks. The slide-plane and the loop-plane are in reality planing approaches, and if we add the number of approaches of these types to the planing approaches for each age group, we find that the total number of planing approaches which each group utilizes increases gradually from 1 at 20 weeks, to 34 at 52 weeks. The loop-slides make their appearance at 20, 24, 28, and 32 weeks.

We may summarize, then, by saying (*a*) that the loop and the slide approaches constitute the two common types of approaches of the younger age groups, viz., 16 weeks to 28 weeks, (*b*) that the planing approach is the typical reaching reaction of the older infants, viz., the 36-, 40-, and 52-weeks groups, and (*c*) that the change in the type of approach from loop or slide to the planing approach occurs between 28 and 36 weeks. In this connection we note that at 32 weeks the total number of loop and slide approaches is 22 and that the total number of planing approaches is 10.

Thumb-Direction

The manner in which infants hold their thumbs is an interesting study. The thumbs of very young infants either hang (point) down or curl under the palm of the hand on the approach, while the thumbs of the older infants usually point in toward the median plane of the infant or down-in. In other words, the thumb of the young infant appears to exercise but a passive rôle in approach, while the thumb of the older infant takes

a very active part in the approach by way of setting itself to contact with the near surface of the cube so that the thumb may exercise real opposition to the fingers in gripping the cube.

We have therefore listed in Table 10, the number of times infants of the several age groups hold their thumbs *down*, *down-in*, or *in* during a large part of the approach. According to this table, the 16- and 20-weeks infants almost invariably hold their thumbs down during the approach (see Figure 1A). Of the 24- and the 28-weeks groups, half of the infants hold their thumbs down and half hold their thumbs down-in. Of the older age groups, 32-weeks to 52-weeks, half of the infants hold their thumbs pointed in and the other half hold their thumbs pointed down-in (see Figures 2A and 2B). An interesting exception to this last statement occurs at 40 weeks when seven infants have their thumbs pointing down. However, upon examining the records, we find after all that in six of these seven cases the infants held a cube in the approach hand, so that they were not free to approach the cube in the manner which they employ in reaching for the first cube.

It sometimes happens that infants change the direction of their thumb-pointing at the completion of the approach. In other words, the thumb may be pointing down during most of the approach and then suddenly pivot inward preparatory to contacting with the cube; or the thumb may be pointing inward during most of the approach and then pivot in a down-in direction at the moment of contact. Inasmuch as we regard

the manner in which an infant holds his thumb during the approach as highly indicative of the type of grasp which follows contact, we have constructed Table 11, to show just how the thumb points at the moment of contact (*final thumb-angle*) regardless of its position during the greater part of the approach.

Table 11 shows that the final thumb-angle for the 20- and 24-weeks infants is usually down, although there are a number of cases where the thumb is down-in and even in. At 28 weeks one-third of the thumb-

TABLE 10

NUMBER OF APPROACHES IN EACH AGE GROUP IN WHICH THE THUMBS OF THE INFANTS POINT DOWN, DOWN-IN, OR IN

	Age in weeks							
Thumb-direction	16	20	24	28	32	36	40	52
Down	21	26	17	16	2		7	
Down-In	1	2	14	19	13	19	11	19
In		1		3	13	16	18	15

TABLE 11

NUMBER OF TIMES FOR EACH AGE GROUP THAT THE VARIOUS DIRECTIONS OF THE FINAL THUMB-ANGLE OCCURRED

Back means that the hand was so pointed down that the thumb pointed back at the infant. *Out* means that the whole hand was turned so that the palm and thumb faced out laterally. *Down*, *Down-In*, and *In* refer to pointing down toward the table, down-in toward the midline of the table, and in above the midline of the table, respectively.

	Age in weeks							
Direction of final thumb-angle	16	20	24	28	32	36	40	52
Back					3	1		1
Out		1	1					
Down		10	14	12	1	1	3	
Down-In		2	6	11	5		1	
In		2	3	13	20	32	32	32

angles are down, one-third are down-in, and one third are in. From 32 weeks to 52 weeks most of the thumb-angles are in. The data on final thumb-angle agree fairly closely with the data on thumb-direction (see Table 10).

The direction of the thumb is an index to the position in which the infant holds his forefinger. For example, when the thumb is down, the forefinger points down; when the thumb points in, the forefinger is usually turned in. The direction of the angle formed by the thumb and forefinger, then, is as much of an index to the kind of grasp which follows the approach as is the thumb-direction itself.

A comparison of *types of grasping* (Table 18) with the *final thumb-angle* (Table 11) shows (*a*) that at 20 weeks and at 24 weeks the final thumb-angle is predominatingly down and that the cube is usually grasped firmly in the middle of the palm, (*b*) that at 28 weeks and at 32 weeks, when the final thumb-angle is undergoing a change in direction from down toward in, the outstanding type of grasp is the lowest form of grip which favors thumb-opposition, and (*a*) that at 36 weeks, 40 weeks, and 52 weeks, wherein the final thumb-angle is usually in or down-in, the higher types of grasp, forefinger types, prevail.

Height of Approach

Table 12 gives the average of the maximal heights of the approach, the standard deviation, and the number of approaches for each of the eight age groups with the forefinger-tip as the point of reference. In obtaining this table we include only those approaches

TABLE 12

MAXIMAL HEIGHT (IN INCHES) OF HAND DURING APPROACH

	Age in weeks							
	16	20	24	28	32	36	40	52
Av. height (inches)	3.3	3.7	3.8	3.9	3.6	3.2	2.4	2.1
S.D.	1.07	1.21	1.59	1.29	1.49	1.94	0.97	0.86
No. cases	10	14	17	23	19	28	21	20

wherein the hand is raised from the table and the forefinger is plainly visible throughout the entire route, because our purpose is to discover just what relation exists between loop and planing approaches and whether or not the height of the hand in reaching is a function of age.

We know that 16- and 20-weeks infants make but short advances toward the cube (see Table 7 under *Distance from cube*); therefore, their respective heights of approach, 3.3 and 3.7 inches, are out of proportion to their lengths. At 24 and at 28 weeks the approach reaches its maximal height, 3.8 and 3.9 inches, respectively, but these advances are for the full distance with the cube in the *S.M.* position. The height decreases slightly at 32 weeks to 3.6 inches, and then drops to 3.2 inches at 36 weeks, 2.4 inches at 40 weeks, and 2.1 inches at 52 weeks. In other words, the four youngest age groups raise their hands relatively high for their somewhat uncertain approaches, the 32- and 36-weeks groups give indications of slicing off the top of this high loop in their profiles, and the 40- and 52-weeks groups straighten the height of the approach to a minimal level, any lowering of which would not permit the hand to clear the one-inch cube.

Adjustment Stages in Approach

The relation of the hand to the forearm is unique. In earliest infancy the arm dominates the hand to a great extent and determines its directional movement and its position. There comes a time, however, when the hand begins to assert itself and finally to take the lead in all prehensile activity. For example, in early infancy the hand is not a specialized organ. The movements of the forearm determine where it shall move and where it shall be placed, and it merely grasps reflexively any object with which the palm contacts. Many errors in direction and position of the hand appear, and all prehensory functions are crudely performed. Later, as the forefinger and thumb assume leadership over the other digits, so that the hand no longer has its paw-like activity, errors in prehensile direction and distance are reduced to a minimum. This shift in functional control in prehension leads us to make a study of hand-direction and of forearm-direction.

A still-by-still analysis of the successive frames of the frontal and lateral motion pictures of infant approach compared with the frames seen in motion discloses four adjustment stages in the patterns of approach. These stages are well defined in all of the circuitous forms of approach but are also distinguishable in the more mature straight approaches (see Figures 1A, 1B, 2A, and 2B). The four stages are: (*a*) The initial adjustment to the cube, during which the infant sets his hand or hands and begins the approach. In many instances in the four youngest groups, "setting" takes the form of pointing at or toward the cube, and he may

or may not raise the hand. In the four older groups the hand takes off in the direction of the cube without any definite pointing, or rises with just a slight advance toward the cube. (*b*) The accelerated advance, in which the hand increases its speed of movement in the direction of forward, outward, or inward, with its actual destination still obscure. At this stage, especially in the circuitous form of approach, no one can safely predict the ultimate goal of the hand. (*c*) The alignment phase, in which the infant aims his hand more directly at the cube (lines up with it), a stage which in the circuitous form of approach often means a considerable change in its direction. (*d*) The culminating approach, in which the infant sets his hand for the cube both as to aim and disposition of the digits and palm. The retardation in speed of approach usually occurs between the third and the fourth stages, or at the fourth stage.

Figures 1A, 1B, 2A, and 2B illustrate the stages in the approach for the following forms of reaching: the angular circuitous slide approach, the very circuitous loop approach, the slightly circuitous planing approach, and the straight planing approach. We obtain the photographs which are typical of these four stages by enlargement of individual frames of the motion film.

The *angular circuitous slide approach* of the 20- and 24-weeks infants (Figure 1A) shows that in this case the reaching for the cube starts before it is actually placed in position. The approach in its fourth stage shows how the hand cuts in short of the cube without touch-

ing it. The approach is angular in that the hand sweeps out laterally and then sweeps in to about the same position from which it started, so that, while the path of the forefinger in moving out and in describes curved lines, an acute angle in the path appears between the second and third stages of the approach. In the second stage we have a good illustration of what looks like thumb-opposition, although we know now that the thumb held in this manner seldom exercises opposition in the case of grasping the cube. The hand during the approach is paw-like in its advance. All fingers remain together so that no one digit leads in pointing at the cube. There is little, if any, body rotation or shoulder extension in this form of approach.

The *very circuitous loop approach* (Figure 1B), which usually occurs at 24, 28, and 32 weeks, is completed without any halt in its advance. The hand is raised and is on its way out to the side and slightly forward, where we find it in the second stage. In the third stage the hand has moved forward and in toward the midline, and in the fourth stage the hand is directly above the presented cube ready to seize it. Note that the thumb in the third stage of the approach is pointing in, which is the typical position at this age for securing a grasp involving thumb-opposition. We note in the first stage that the hand is raised almost directly up to a considerable height above the table top in the manner of a loop profile. In the fourth stage it is quite evident that the hand will take the cube either with a palm grasp or a superior palm grasp because the entire hand is being brought down upon the cube so that the palm may contact with it.

The *slightly circuitous planing approach* is the typical reaching reaction of the 40-weeks infants. In the illustrated case (Figure 2A), the first stage shows the right hand as it is rising from the table edge. In the second stage the hand has moved considerably forward as well as upward. In the third stage the hand is planing down toward the cube, and in the fourth stage two fingers are just over and beyond the cube and set for a forefinger grasp. Throughout the approach the infant directs the index and medius fingers so that they will pass immediately above the cube. We call this forefinger-pointing. The thumb points inward-downward so that on reaching the cube this digit will contact with the cube at its near face.

The 52-weeks infant uses the *straight planing approach* (Figure 2B). The height of this approach is not as great as the height of the slightly circuitous planing approach, although the hand planes down in the same manner as it did in the latter approach. The forefinger leads in directing the approach and the thumb points inward until the fourth stage, when its direction is inward-downward. The hand carries out a better planing motion and describes a straighter line in reaching at 52 weeks than at 40 weeks. A comparison of these illustrated forms of approach shows that body rotation and forward shoulder extension become increasingly greater as one passes from the earlier to the later forms of approach.

Hand-tilt During Approach

The tilt of the hand during the approach may have little significance, but we find that from 16 to 24 weeks,

where the hand is raised from the table for the approach, there is a tendency for the palm and fingers to hang slightly down at least during some stage in the approach. This tendency disappears at 28 weeks. Between the ages of 16 to 24 weeks the tilt of the hand varies greatly during the progress of the approach. For instance, up to 24 weeks the tilt of the hand may vary at any stage of the approach from tilting down to tilting up, while from 28 weeks to 52 weeks the hand is either held horizontally or tilted slightly upward at the finger-tips. In studying hand-tilt, we use only those cases wherein the infant raised the hand from the table on the approach to the cube. The number of cases available, wherein a fairly accurate determination of hand-tilt can be obtained, varies for the several age groups (see Table 13). Although there are unclassifiable approaches, as far as hand-tilt is concerned, there are, nevertheless, three distinguishable forms. The first form is where the hand and fingers, upon being raised, hang down or point down at a sharp angle and as the hand is thrust forward the fingers and hand finally attain a horizontal position. This form occurs infrequently at 16 weeks and at 20 weeks. The second form, which occurs uniformly at all ages, is where the hand and fingers parallel the table top during the entire course of the approach. In the third form of approach the hand starts horizontally, then tilts so that the fingers point up during the first half of the approach. The hand then returns to the horizontal or tilts slightly downward during the second part of the approach. The latter form occurs at all ages, except at 16 weeks, and is most common at 52 weeks.

Aim of Approach

We offer the following general statement to characterize the hand activity in general during the approach. At 16 weeks the fingers generally curl down or hang down, although occasionally they may be found fully extended. However, they are seldom pointed upward. At 20 weeks the hand is generally stiffly projected in line with the forearm with very little wrist action. At both 16 and 20 weeks the upper limb of the infant behaves less like a forearm and hand than it does like a foreleg and paw of an animal. As a matter of fact, the arched approaches that we find at these ages are really nothing but modifications of pawing and scratching movements. At 24 weeks the hand is as yet not very independent of the forearm. The latter apparently determines the direction of the former on the approach, as is the case at 16 and at 20 weeks. Often at these ages the fingers point down during the approach in a manner characteristic of the scooping- or corralling-approach action. At 28 weeks we find indications of

TABLE 13

Frequency of Occurrence in Each Age Group of the Various Types of Hand-Tilt During Approach

Hand-tilt refers to the direction in which the digits point as the hand reaches for the cube.

Types of hand-tilt	Age in weeks 16	20	24	28	32	36	40	52
Hand tilting down, then horizontal	2	1	0	0	0	0	0	0
Hand horizontal throughout	2	1	4	6	3	3	7	4
Hand horizontal, then up, then horizontal or down	0	4	3	5	5	5	6	9

the hand divorcing itself from forearm control. The aim for the cube is better directed, there is less variation in hand-tilt during the approach, and there is greater steadiness in hand control. The infant is now beginning to point to the cube with the first two fingers instead of with the forearm and hand. The records show that 28 weeks is the critical age in prehensile advance, for, not only is the infant beginning to aim differently at the cube, but he is also altering the vertical profile of the approach (Table 9). The planing approach makes

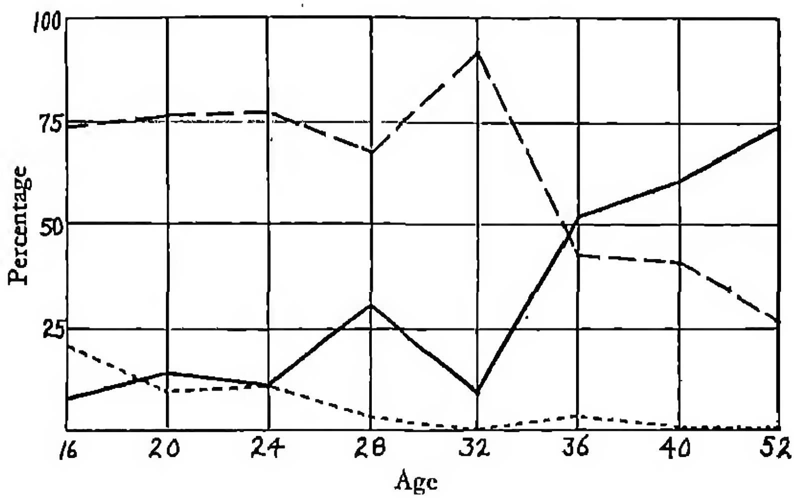


FIGURE 8

PERCENTAGE OF STRAIGHT, CIRCUITOUS, AND BACKHAND APPROACHES (BY EMPTY HANDS ONLY) EMPLOYED BY THE VARIOUS AGE GROUPS

This figure also shows the gains and losses in the relative number of these forms of approach by the successive age groups.

Straight ————
Circuitous — — — —
Backhand - - - - -

its appearance for the first time with some consistency (Figure 8), and the large number of combinations of the loop-slide and planing forms (Table 9) indicate the presence of maturational forces favoring the use of the planing type of approach.

Figure 8 shows (in percentages) the relative amount of straight, circuitous, and backhand approaches employed by the eight different age groups and the gains and losses in the relative number of these forms of approach by the successive age groups. The percentage of infants who employ a given form of an approach are indicated by the abscissi and the age groups are denoted by the eight ordinates. The graph includes approaches by empty hands only.

At 32 weeks there is, in general, good directional control during the approach (see Table 22, in columns *Poor direction*, *Over-reaches*, and *Under-reaches*). There are still a number of combinational forms of the approach (Table 9), and there is a remarkable advance in the method of pointing, favoring the thumb and forefinger (Tables 14 and 15). At 36 weeks the planing approach predominates, although there is a scattering of other forms. The forefinger and thumb dominate both approach and grasp. Practically all the aiming is done with the forefinger and thumb and there is more flexibility in the digits in general. The fingertips have practically replaced the palm in gripping (Table 18), and they appear to be functioning as much for informatory purposes as for gripping purposes. At 40 weeks there is practically only one form of approach, and that is the planing type (Table 9),

in which the directional control is excellent. Aiming is done with forefinger and thumb. There can be no doubt that the neuro-musculature of arm, hand, and digits has attained practically an adult value. The refined form of grasp and superior type of manipulation of the cube indicate that the finger-tips are serving not only to grip but to sense the object. At 52 weeks we have a still greater refinement of all the processes of approaches and grasp described at 40 weeks.

Aim of Forearm

In view of the above facts we present separately the results of our study of the aim of the forearm and the results of a similar study of the aim of the hand during the course of the approach. Table 14 shows the aim of the forearm (elbow to wrist) at the last stage of the approach. For young infants, the hand forms practically a straight line with the forearm and moves with it somewhat like the disk on the end of a pendulum, although a certain amount of hand-rotation does occur. In older infants the wrist demonstrates greater flexibility; for movements of flexion, extension, adduction, and abduction occur with increasingly greater frequency.

Table 14 shows that only the younger infants of 20, 24, and 28 weeks point their forearms toward the medial side of the cube during the last stage of the approach. This direction of pointing corresponds with the cutting-in approaches at this age (see page 184). There are only two exceptions to this rule, one at 36 and one at 40 weeks. Pointing directly at the cube or above it is very common at 20, 24, and 28 weeks and quite common from 32 weeks to 52 weeks. Pointing at or above the

TABLE 14

FREQUENCY OF OCCURRENCE IN EACH AGE GROUP OF THE VARIOUS AIMS OF THE FOREARM AT THE END OF APPROACH

Median side refers to pointing at some position between the cube and the infant's trunk. *At cube* refers to pointing directly at the cube or above it. *At side of cube* signifies pointing at the near lateral side of the cube.

	Age in weeks						
Aims of forearm	20	24	28	32	36	40	52
Median side	4	5	2	0	1	1	0
At cube	5	9	12	7	9	6	11
At side of cube	1	4	9	16	14	17	15

near lateral side of the cube increases from 20 weeks up to 32 weeks, and is the common form of pointing the forearm from 32 weeks to 52 weeks.

A study of some of our detailed data[4] reveals that for the 20, 24, 28, and 32 weeks groups (if we follow the highest figures for each stage of the approach) the forearm, regardless of its direction in the first stage, remains out, or is swung out to point past the lateral side of the cube for the second and third stages. The forearm is then drawn in to point at the cube or its near side in the fourth stage. This outstanding action is the typical forearm movements for the circuitous approach. From 36 weeks to 52 weeks, inclusively, the forearm does not customarily swing out laterally, but "lines up" directly with the cube or its near lateral side and then planes straight toward the cube in the manner typical of the straight approach.

AIM OF HAND

Aim of hand signifies the aim of the thumb-and-

[4]See footnote 2, page 132.

TABLE 15

FREQUENCY OF OCCURRENCE IN EACH AGE GROUP OF THE VARIOUS AIMS OF THE HAND AT THE END OF APPROACH

Down signifies that the thumb and forefinger are pointing vertically down, *Down-in* signifies pointing partly down and partly medianward, *In* signifies that the thumb and finger are pointed horizontally inward on the table with the hand practically pronated, *At* signifies the same as *In* and *Down-in* with the exception that now the cube is within that portion of the table which subtends the thumb-forefinger angle.

	Age in weeks						
Aims of hand	20	24	28	32	36	40	52
Down	10	12	8	1	0	0	0
Down-in	0	2	8	2	0	1	0
In	1	1	2	5	8	3	2
At	1	3	7	16	18	21	24

forefinger angle. Table 15 shows that the younger age groups, 20- and 24-weeks, aim the hand *down* at the final stage of approach, so that the palm may settle directly on the cube in grasping. Aiming the hand *down-in* prevails only at 28 weeks. Pointing *in* by the hand toward the infant's median plane prevails to a slight extent at all ages and signifies that the hand stopped short of the cube at the end of the approach. When approaches of this type terminate successfully the hand points *at* the cube. The number of times that infants point *at* the cube increases with the age of the infants, from 1 time at 20 weeks to 24 times at 52 weeks. Therefore, we may say that the younger infants usually point the hand *down* at the end of the approach, so that the cube may be grasped with the hand directly above the cube, and that the older infants point the hand *in* (*at*) at the end of the approach, so that the three digits on the radial side of the hand may function most prominently in grasping the cube.

Our data[5] indicate that the aim of the hand is predominatingly *down* during the entire progress of the approach for the three youngest age groups (16 weeks to 24 weeks). At 28 weeks, the aim, usually *down* for the first half of the approach, may be *down*, *down-in*, or *at* during the latter part of the approach. At 32 weeks and at 36 weeks the aim is usually *in* at first and then *at*. At 40 weeks and at 52 weeks, the aim, which is *in* or *at* at first, is *at* during the final stage of the approach.

If we combine the pointing of the forearm with the pointing of the hand (Tables 14 and 15), we discover that for the 16-, 20-, and 24-weeks groups the circuitous approach occurs with the hand pointing down, so that grasping, if it takes place, finds the entire hand covering the upper face of the cube, a condition which usually results in a full-palm grip (see Table 18). The circuitous approach of the 28-weeks infant is followed by a full-palm grip or a radial-palm grip, for at this age the final aim of the forearm may be either at the cube or at its side. At 32 weeks the conclusion of the circuitous approach finds the forearm oftenest directed at the side of the cube with the hand aimed at the cube, so that the grasp has to be a radial-palm grip or forefinger-thumb grip. The circuitous and straight approaches of the 36-, 40-, and 52-weeks infants can lead only to a type of grasp which involves principally the first two digits. It is necessary to explain, in the case of the five older age groups, how it happens that an infant whose forearm is directed

[5]See footnote 2, page 132.

straight at the cube can have the hand pointing in at the cube. We have already mentioned that the hand of the 16-, 20-, and 24-weeks infants appears to lie in the same straight line with the forearm. For the older children, however, the hand is often adducted outward at the wrist so that the fingers are directed out somewhat laterally as well as forward. This change in the direction of the hand is enough to place the thumb-forefinger angle almost in a direct line with the forearm; hence, while under ordinary conditions the forearm is pointed at the side of the cube for a forefinger-thumb grip, under the conditions just described it is easy to see that the same form of grasp may occur when the arm is pointed directly at the cube.

The initial position of the hand, while it does not determine the nature of the approach, may exert a certain influence on its route. If the hand points diagonally in on the table, the infant either sweeps his hand out toward the cube on a wide backhand movement, or he withdraws the hand to the table edge to point at the cube before he reaches for it. If the hand points diagonally out, the infant sweeps it in on a wide arc toward the cube or he draws the hand in toward him, orienting it to point at the cube preliminary to the approach. If the hand points straight ahead, no preliminary adjustment of the hand occurs, although occasionally we note that it is raised and poised for just a moment.

Hand-Rotation on Approach

One observes that when infants reach for objects, the approach-hand sometimes rotates from supination to pronation, or from semi-pronation to full pronation

TABLE 16

FREQUENCY OF OCCURRENCE IN EACH AGE GROUP OF HAND-ROTATION ON APPROACH

Hand-rotation	16	20	24	28	32	36	40	52	Total
	Age in weeks								
Approach hand:									
Pronate throughout	8	14	14	8	8	7	9	7	75
Semi-pronate throughout	0	1	1	3	0	1	2	3	11
Sweeps in: palm-in to pronate	1	2	5	10	11	14	7	13	63
Sweeps out and in: pronate to palm-in to pronate	1	1	0	4	3	2	3	2	16
Sweeps out: pronate to palm-in	0	0	1	0	1	0	0	0	2
Sweeps in: pronate to palm-in	0	3	3	1	2	3	2	4	18
Sweeps out and in: palm-in to pronate to palm-in	0	4	0	2	1	1	0	0	8
Sweeps out: palm-in to pronate	3	4	2	0	0	0	1	1	11
Other hand:									
No rotation	33	31	29	21	28	22	28	28	223
Rotates in	0	7	8	9	3	9	5	1	42
Rotates out	2	2	2	6	3	5	3	7	30

or in reverse direction, and sometimes no observable rotation occurs. The question arises then as to whether the younger infants differ from the older infants in the way they rotate their hands while reaching for objects. In conducting this investigation on the approach-hand we also noted the activities of the other hand.

Table 16 attempts to indicate the synchronous behavior of the two hands during the approach, when the approach hand is empty. The age groups are indicated in the first column to the left, the types of movements of the approach-hand head the succeeding eight columns under the main heading, *approach-hand,* and the three succeeding columns give the direction of the rotation of the *other hand.* The numerals in the cells under *approach hand* indicate the number of infants of the several groups who move their approach hands in the manner indicated at the headings of the eight

columns. The numerals in the cells under *Other hand* indicate the number of times the hand which is not making the approach moves in the manner indicated at the headings of the three columns.

The data of Table 16 show that, regardless of the shift in position in its advance toward the cube, the approach hand for the three younger groups is generally pronated throughout. From 28 weeks to 52 weeks, however, the hand which sweeps in, on, or above the table, with the accompanying hand-rotation from palm-in to pronate, is more prominent than the hand which remains pronated throughout. (Rotation from palm-in to pronate includes any hand-rotation from supination or palm-in to semi-pronation or complete pronation.) The pronated hand of the younger infant differs from the pronated hand of the older infant mainly in that for the former the thumb points down while for the latter it points in toward the midline. These data combined with the two commonest forms of approach, the circuitous and the straight (Table 8), enable us to contrast the approaches of the younger groups with the approaches of the older groups with respect to the activities of the other hand. For the 16-weeks groups, who usually complete but one-half of their circuitous approaches, the other hand seldom moves. From 20 weeks to 40 weeks, the other hand, during a circuitous or slide approach, usually remains quietly throughout, otherwise it generally rotates inward from supination, palm-in, or semi-pronation in mimicry of the approach-hand. Occasionally, this hand moves in or out across the table, but it usually remains relatively fixed or ad-

vances slightly forward with the approach-hand. There is very little rotation by the second hand for the 52-weeks group, but rotation, when it occurs, is usually from pronate toward supination and away from the cube. When either hand is at the infant's mouth or at the near edge of the table above the midline, it is usually palm-in, occasionally palm-up, but seldom pronated or semi-pronated. When the hand is some distance out above the midline of the table it is usually semi-pronated and sometimes fully pronated. When the hand is aloft laterally, it is likely to be pronated or even palm-out.

Touching and Grasping

Younger infants differ from older infants in the manner in which they reach for objects and also in the manner in which they touch and grasp objects. When an infant of 20 or 24 weeks fails to grasp an object, it is because he misdirects the hand or misjudges the distance. When an infant of 40 or 52 weeks fails to grasp an object it is usually because he does not desire the object or because he merely wishes to push it about. The manner in which infants grasp the cube, however, is perhaps not only the most interesting process in prehensory activity of the infant, but also the most indicative of infant development. For example, we find that up to 20 weeks of age, infants evidence so very little thumb activity in grasping, that grasps in which thumb-opposition occurs are very rare. From 24 weeks to 32 weeks, however, thumb activity increases so rapidly that practically all grasps by infants from 32 weeks to 52 weeks of age show active thumb-opposition. Be-

tween 20 weeks and 32 weeks we find about an equal number of cases of no thumb-opposition and thumb-opposition in grasping (Table 18).

Table 17 records the number of contacts, the number of pursuits, the number of pursuits after contact, the number of contacts following pursuit, and the number of grasps for the infants of the different age groups in the three situations of this investigation.

We record a contact whenever any portion of an infant's hand or wrist touches the cube without grasping it. When a contact resolves immediately into a grasp, a grasp only is recorded. Thus, a contact means failure to grasp the cube. The number of contacts for the several groups increases from 16 weeks to 28 weeks. From 32 weeks to 52 weeks the number of contacts is less than at 28 weeks.

The data show that up to 32 weeks some infants in each group do not succeed in contacting with the cube, although the number of these infants decreases with

TABLE 17

NUMBER OF INFANTS IN EACH AGE GROUP WHO SUCCEEDED IN CONTACTING AND GRASPING THE CUBE

No. contacts refers to the number of infants who at first contact the cube without grasping it; *No. pursuits,* to the number of these infants who continue to pursue the cube; and *Contacts again,* to the number who succeed in touching the cube for the second time following the pursuit.

	Age in weeks							
Contacts and grasps	16	20	24	28	32	36	40	52
Number of contacts	3	18	22	32	19	25	25	19
Number of pursuits	0	13	20	31	18	25	22	19
Number of "contacts again"	0	12	20	31	18	25	22	19
Number of grasps	0	6	16	26	24	30	26	29

age. According to some of our additional data,[6] infants usually touch or grasp the cube in the first situation and sometimes fail to reach for the second or the third cube when they are presented. It seems, then, that, inasmuch as these failures by some of the groups, such as the 28-weeks and the 32-weeks groups, in touching or grasping the cube usually occur in the second-cube or third-cube situations, we are safe in concluding that the presence of the cubes already held in the infants hands interferes with the process of grasping the third cube.

Table 17 shows that at 16 weeks infants often attempt to reach, but seldom succeed in touching, the cube. Preyer (45) reports that one girl at 18 weeks and two boys at 17 and 19 weeks, respectively, for the first time grasp at objects which they really desire to possess.

At 20 weeks one-half (18) of the infants contact with the cube (in the three situations there are 40 infants), and at 24 weeks all of them are able to reach it, if they so wish, and about one-half of them grasp it. From this age on, all infants generally grasp the cube. Finger contacts far outnumber contacts by the palm and by the edge of the hand.[7] With the exception of the 16-weeks group, infants who touch the cube without successfully grasping it pursue and generally touch it again or grasp it. (Note that in *Pursues cube* and *Contacts again* there are for each group about as many *pursuits* and *contacts again* as there are first *contacts*.) The table does not record the total number of times

[6]See footnote 2, page 132.
[7]See footnote 2, page 132.

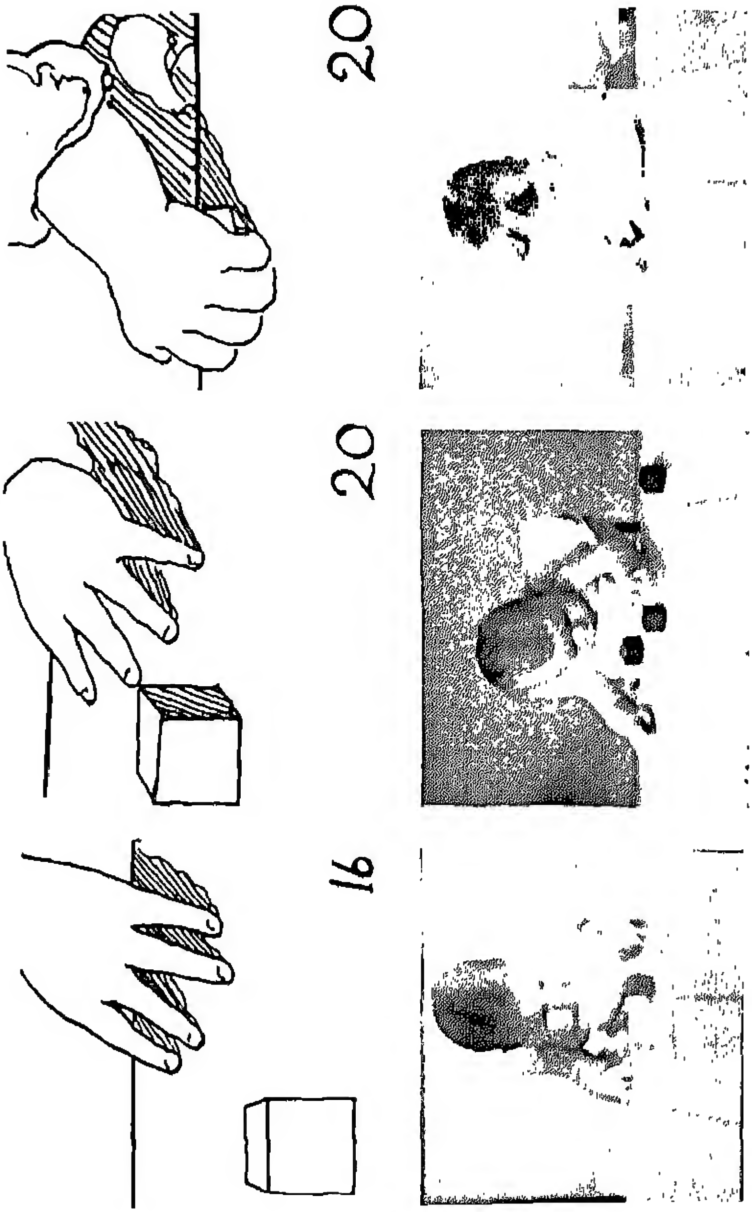
infants touch the cube for the following reasons: If one hand makes all the contacts, only one contact for that hand is recorded under *No. of contacts.* If both hands contact with the cube several times, one contact by each hand is recorded. If both hands contact simultaneously with the cube, one contact only is recorded. The number of grasps increases with age up to 28 weeks, the older groups having approximately the same number of grasps as the 28-weeks group.

Hand-preference in touching the cube alternates with age up to 36 weeks and then favors the right hand at 40 weeks and remains with this hand at 52 weeks.[8] In grasping and in holding the cube, no definite hand-preference is apparent until we reach the 40- and 52-weeks groups, when the right hand definitely surpasses the left hand. The number of "holds" increases up to 28 weeks and then remains constant for the remaining groups. The hands often cooperate in grasping the cube. This cooperation is quite marked at 20 weeks and at 24 weeks, and is present to a lesser degree at 32 weeks, 36 weeks, and 40 weeks. According to our data, also, the hands of the infant cooperate in holding the cube after it is grasped, a tendency which is particularly strong at 24 weeks. Perhaps this tendency toward cooperation is an indication of the uncertainty of the infant's grip.

Types of Grasp

Infants from 16 weeks to 52 weeks of age vary greatly in their manner of grasping objects. Very young in-

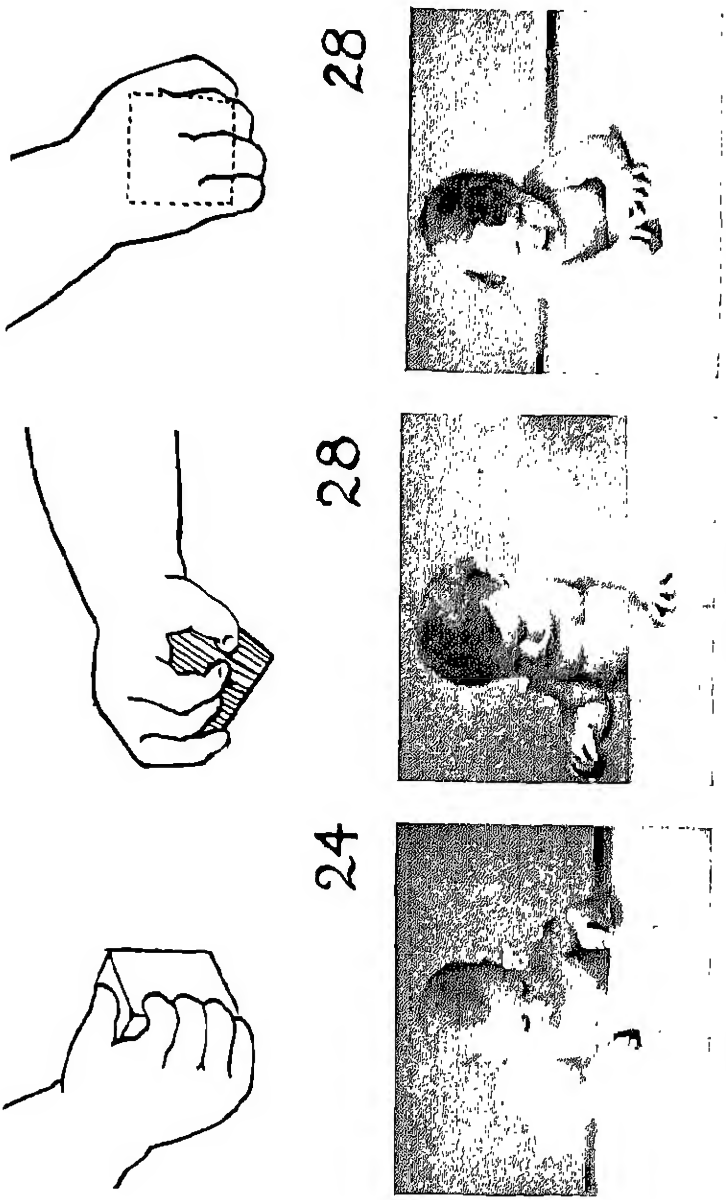
[8]See footnote 2, page 132.



No contact

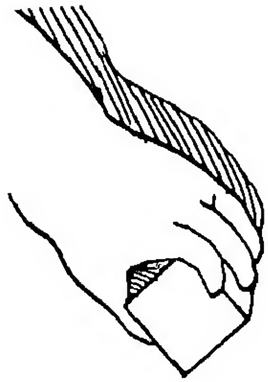
Contact only

Primitive squeeze



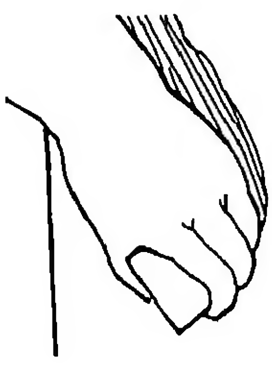
Squeeze grasp — Hand grasp — Palm grasp

FIGURE 9A
TYPES OF GRASP



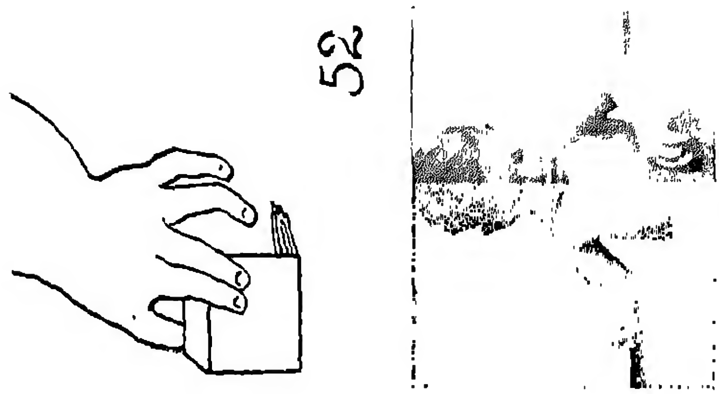
36

Inferior-forefinger grasp



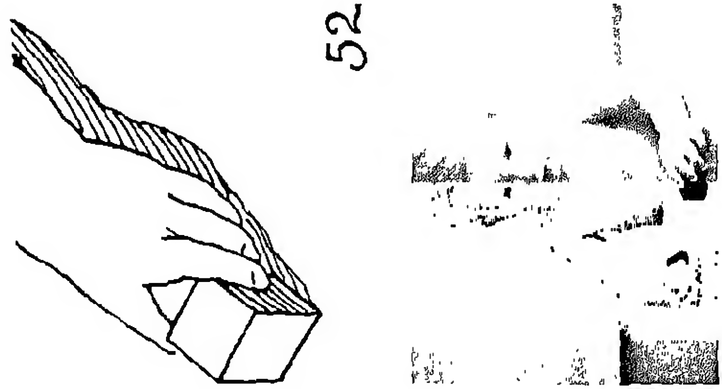
32

Superior-palm grasp



52

Superior-forefinger grasp



52

Forefinger grasp

FIGURE 9B
Types of Grasp

fants make no use of the thumb in taking and holding objects. They depend entirely upon the palm and massed fingers for gripping. In older infants the thumb and forefinger form the principal support in grasping and holding. The stilling process of studying the motion pictures reveals eight types of grasp which arrange themselves in an orderly sequence quite consistent with the growth of the infant. Naturally, there are infants who do *not* succeed in reaching the cube, and there are also infants who reach the cube but cannot grasp it. We add these two items to our grasp series to complete our story of prehension for all infants from 16 to 52 weeks of age. Each of these ten types of grasp is fully illustrated by photographs and drawings in Figures 9A and 9B. The photographs are enlargements from the motion films which were studied for cube prehension. Each photograph represents one kind of grasp, the type of which is stated beneath the photograph. Above each photograph is an enlarged drawing of the hand, which shows clearly the relative position of the palm and digits to the cube.

We have, then, the following types of grasp in order of refinement:

1. *No contact* includes all instances wherein infants for some reason fail even to touch the cube.

2. *Contact only* includes instances in which infants succeed in touching but not securing the cube.

3. *Primitive squeeze* the infant thrusts the hand beyond the cube and corrals it by pulling it toward him on the table with thumb, wrist, or hand until he succeeds in squeezing it against the other hand or the

body. The primitive squeeze is not a true grasp for the hand does not actually grip the cube.

4. The first form of actual grasp is the *squeeze grasp*. The hand, palm-in, approaches the cube laterally on the table to envelop it. At the moment of contact the fingers close on the cube so as to press it strongly against the heel of the palm with the thumb extended on the upper face of the cube. This grasp is clumsy and usually results in failure to hold the cube, at least no infant has succeeded in raising the cube from the table with this grasp.

5. In the *hand grasp* the infant brings the pronated hand down paw-like fully upon the cube, curls the fingers down on the far face of the cube with the thumb paralleling the digits on the adjacent surface, and presses the cube firmly against the heel of the palm. The fingers appear to be of equal importance in grasping and the thumb seems to lack tonicity.

6. The *palm grasp* is accomplished by setting the pronated hand down on the cube so that the fingers curl over the top and far down on the further face with the thumb pointing down against the near face to oppose the fingers in forcing the cube against the palm. We have now for the first time active thumb-opposition. *This new feature in the thumb repertoire of functions* and the simultaneous budding into prominence of the forefinger are mainly responsible for the higher types of grasp which follow. Up to this point all digits function in holding the cube in the middle of the palm. From now on only the first three digits function prominently in grasping so that we find the cube no longer

in the middle of the palm but shifted to the radial edge of the hand. A faulty palm grasp becomes a hand grasp. As a matter of fact, the hand grasp is often due to the failure of the thumb to orient itself properly for opposition to the other digits.

7. In the *superior-palm grasp* the infant sets only the radial side of the palm down on the cube with the thumb against the near side opposing the first two fingers, which are curled down on the far side. In closure, the digits press the cube against the thumb and palm.

8. The *inferior-forefinger grasp* greatly resembles the superior-palm grasp. There is the same thumb-forefinger opposition, but the digits at the end of the approach point more medianward than downward (tendencies of this change of pointing appear in the superior-palm grasp), an angle of approach which makes thumb-opposition simple, and the cube is no longer pressed against the palm. This type of grasp represents an achievement of no small degree for the infant, for here is a clear demonstration of the fact that the digits are beginning to act independently of the palm in grasping and holding. Heretofore, the infant uses the palm in grasping to make up for the shortcomings in gripping by the digits. Now he finds that he can make the necessary fine adjustments of the proper digits to secure his grasp and can maintain the delicately balanced pressure of the digits against the near and far faces of the cube to insure its being held. We may say that the advance in grasping from the palm type to the forefinger type marks the change from a

three-surface grasp to a two-surface grasp—a tri-directional pressure gives way to a di-directional pressure. The inferior-forefinger grasp is not a true finger-tip grasp, however, for the cube is still well up toward the palm so that a considerable portion of the palmar surfaces of the digits contacts with the cube.

9. The *forefinger grasp* is essentially a finger-tip grasp. The cube is well out on the tips of the first three digits (sometimes four digits) with the thumb opposed to the fingers. Up to this point, all types of grasp require that the hand come to rest on the table before the cube can be raised. Thus the table serves as a base or leverage point for lifting the hand after it grasps the cube. In the forefinger type of grasp the digits are pretty well extended, distinct flexion appearing only at the metacarpophalangeal joints. In earlier forms of grasp the digits curl about the cube.

10. The *superior-finger grasp* is exactly similar to the forefinger grasp, with the exception that the infant in grasping does not have to place any portion of his hand on the table top to aid the placement of the digits against the cube, nor does he require the table for leverage in raising the cube. The hand alights on the cube, attains its grip, and raises the cube deftly and neatly. True, the hand may touch or brush the table as the hand settles on the cube, but the presence of the table about the cube is not essential to grasping or raising it.

Table 18 shows the number of each of the above ten types of grasps which occur for each age group. In this table we record but one grasping reaction by each infant in each of the three situations. Hence, if an in-

fant grasps a cube several times, we record but his first grasp. Most of the infants who are able to accomplish the act of grasping secure the cube. There are only one or two infants in each group who do not attempt to grasp at least one of the cubes. A *contact* is recorded only when a touch is not followed by a grasp. We find that *no contact* appears most frequently at 16 weeks, while *contact only* and the *primitive squeeze* appear to some extent at 20 weeks. We find that the *squeeze grasp* occurs most frequently at 24 weeks, that the *hand grasp* occurs oftenest at 28 weeks, and that the *palm grasp* occurs frequently at 24 weeks and occasionally at 28 weeks, 32 weeks, and 36 weeks. The superior-palm grasp is very common at 28 weeks and at 32 weeks, while the inferior-forefinger grasp functions strongly at 36 weeks and at 40 weeks. A number of forefinger grasps appear at 36 weeks and at 40 weeks, but this type of grasp is the predominating type at 52 weeks. The superior-forefinger grasp is not fully developed until some time later than 52 weeks and appears only once in our study, at 52 weeks. However, a study of 56 weeks and older infants reveals a number of the superior-forefinger type of grasp.

The complete data on contact and grasp permits the following conclusions:

1. It is unlikely that 16-weeks infants will touch the cube.

2. A number of the 20-weeks infants will touch, and a very few will grasp, the cube, and the type of grasp is likely to be a primitive squeeze grasp.

3. Most of the 24-weeks infants will reach the cube,

TABLE 18

Frequency of Occurrence in Each Age Group of the Various Types of Grasp Used in Securing the Cube

Type of grasp	Age in weeks 16	20	24	28	32	36	40	52
Superior-forefinger								1
Forefinger						4	5	15
Inferior-forefinger					4	16	15	10
Superior-palm				13	12	3	4	1
Palm		1	7	6	5	4	1	
Hand		1	2	7	2	3	1	2
Squeeze		1	6		1			
Primitive squeeze		3	1					
Contact	3	8	14	10	5	6	10	7
No contact	32	25	9	3	5			

half of them will merely touch it, and the others will grasp it, usually with a squeeze or a palm grasp.

4. All of the 28-weeks infants can reach the cube, several of them will only touch the cube in the second and third cube situations, but most of them will grasp it. The superior-palm grasp predominates, but the hand grasp and the palm grasp frequently occur.

5. The 32-weeks infant will usually grasp the cube except in the third cube situation. At this age the superior-palm grasp occurs most frequently, but we may expect the palm grasp and the inferior-forefinger grasp to put in an occasional appearance.

6. The 36-, 40-, and 52-weeks groups can easily, and usually do, grasp the cube. The 36- and the 40-weeks groups generally use the inferior-forefinger grasp, but other types, such as the superior-palm grasp and the forefinger grasp, occur infrequently. The 52-weeks group employ the forefinger grasp oftener than they employ the inferior-forefinger grasp.

It is interesting to note that when a cube is displaced

almost out of reach the infant generally resorts to a lower sort of grasp than the type he usually exhibits in securing the cube. Some of the types of grasp recorded for each group are due to this lower form of behavior.

We find that as infants increase in age there is a tendency to discontinue the simultaneous use of the two hands in grasping, although the infants may reach toward the cube with both hands. For example, at 20 weeks, of the 6 grasps recorded, 2 are definitely double-hand grasps,[9] 2 are single-hand grasps requiring the assistance of the other hand, and 2 are purely single-hand grasps. At 24 weeks, 9 of 16 grasps are distinctly single-hand grasps, while at 28 weeks 18 of 26 grasps are single-, and for the remaining groups the percentage of purely single-hand grasps increases until at 40 weeks all but one grasp are single-, and at 52 weeks only 2 of a total of 29 grasps are not single-hand grasps.

Up to 36 weeks visual attention to the cube is requisite to successful grasping, for, on the occasions on which the regard leaves the cube before the approach is completed, the hand fails to touch the cube. However, at 40 weeks, 2 approaches of this type hold true to their courses and end in grasps; and, at 52 weeks, 6 excellent examples of well-directed approaches, of which only the first or second stage benefit by vision, result in grasps. Coordination of trunk, arm, and hand has reached a fairly high level to render possible so perfect an operation of the mechanism of reaching and grasping.

There is an intimate relationship between approach

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[9]See footnote 2, page 132.

and grasp. While the nature of the approach influences the nature of the grasp, it does not determine its type. Conversely, it is the type of grasp which the infant seeks to secure that determines the aim of the approach, for, as we have already pointed out, an infant aims straight for the cube to procure a palm hold and points for the near lateral side of the cube for a forefinger grasp. A comparison of the distribution of types of grasp (Table 18) and of the forms and direction of approach (Table 8) discloses the relationship between the former and the latter.

As there are no grasps as 16 weeks, no information concerning the relation of approach and grasp is available except by inference. The zigzag, circuitous form of approach predominates over the backhand and straight forms, and we are quite certain that, had these young infants grasped the cube, a lower type of grasp involving the palm grip would have resulted. In fact, this statement is practically a certainty, for, in an investigation now taking place, in which the cube is placed in the infant's hand, the type of grasp displayed is always a hand or a squeeze grasp. These facts tend to link the circuitous approach with the palm-grip type of grasp.

However, for the other age groups, there is no doubt of the direct connection between the form and aim of the approach and the type of grasp. At 20 weeks and at 24 weeks, all grasps are of the full-palm type, the circuitous approaches far outnumber all other forms, and the aim is generally directed straight at the cube or the hand cuts in short of its mark, both of which

favor a full-palm grasp. These young infants attempt to get all their digits and most of the palm against the cube. At 28 weeks, the full-palm and superior-palm grasps appear in equal number, the circuitous approach predominates, although the straight form is infrequently present, and the aim of reaching, while it still is often directed fully at the cube by a margin of 14 to 8, is often directed at the side of the cube.

At 32 weeks a great majority of the grasps are of the superior-palm and forefinger variety, the form of approach is circuitous, and its aim is directed largely at the near lateral side of the cube, which aim favors a grasp by the first three digits. At 36, 40, and 52 weeks the higher types of grasp, which involve principally the use of the thumb and forefinger, greatly outnumber the other types. The approaches are either slightly circuitous or straight, and their aim is directed generally at the side of the cube. Although a number of the forearms are directed at the cube, these approaches occur largely in the second and third cube situations, in which instances the approach-hand is often encumbered with one of the other cubes.

Additional Facts Concerning Grasp

Infants of the older groups usually grasp the presented cube as soon as it is placed in the S.M. position, while infants from 16 weeks to 24 weeks of age usually do not grasp the cube until it has been placed in the N.M. position.

These differences in the time required to grasp the cube are perhaps due not so much to such anatomical conditions as the difference in the length of trunk and

arm of the older and younger infants as to misjudgments of direction and distance and to the inability to equilibrate the body and extend the arms properly.

Table 23 shows that the difference in arm length of 6-months and 12-months infants is about 1.5 inches. No one will deny that older infants maintain better equilibrium than do the younger infants (see page 250). We have already shown (page 171), that younger infants digress more from the straight line, and often change their direction, in reaching for the cube. Table 22 indicates that the number of poorly directed approaches (see *Poor direction*) and approaches which fall short of their mark (see *Under-reaches*), as compared with the number of grasps by these groups (see Table 17), is greater for the lower age groups than for the higher age groups.

One expects to find that younger infants and older infants differ as to the speed with which they grip the cube after they have reached it, that the younger infants will displace the cube farther from its original position and adjust the hand oftener before they firmly grip the cube. Table 19, under *Time up to grasp,* shows that the number of seconds that elapse from the beginning of the situation to the moment that infants grasp the cube decreases from 16.5 seconds at 20 weeks to 3.0 seconds at 32 weeks, after which the time remains fairly constant.

Additional Grasping Data

Table 19 shows for each of the several age groups the time (seconds) required to grasp the presented cube, the time (in motion-picture frames) required to grip

TABLE 19

MEDIANS OF MEASURES OF ADDITIONAL ACTIVITIES IN THE GRASPING BEHAVIOR OF THE VARIOUS AGE GROUPS

Measure	Age in weeks							
	16	20	24	28	32	36	40	52
Time up to grasp (seconds)		16.5	11.0	6.3	3.0	4.0	3.0	3.3
Actual grasp-time (frames)		24.0	15.0	20.5	9.0	11.0	8.0	5.5
Amount of cube displacement (inches)		3.0	2.5	1.8	1.0	1.0	0.5	0.5
Number of extra adjustments		1	1	1	1	1	0	0
Number of infants grasping	0	1	5	12	11	11	11	12

the cube after reaching it, the number of inches the cube is displaced before it is grasped, and the number of times the hand is readjusted for the grasp before the cube is firmly held. The items of investigation are listed at the left of the table, the age groups are indicated at the top, and the number of infants of each group who grasp the cube are indicated at the foot, of the several columns. The numerals in the cells of the table are the medians of the measures of the activities for the different age groups. The table includes only the first cube situation.

Closure time (*actual grasp time*) is less for the older groups than for the younger groups, decreasing from 1.5 seconds (24 frames) for the 20-weeks infants to less than 0.5 seconds (5.5 frames) for the 52-weeks infants. Although the decrease is decisive, the development of grasp itself, as manifested in the types of grasp for the successive age groups (see pages 220-221), interferes with regularity of diminution of speed in gripping the cube. For example, the reduction in the time of grasp from 28 to 32 weeks is due to the fact that the infants of both groups use principally the same type of grasp—

the superior-palm grasp, in which we expect the older group to be more proficient. At 36 weeks, however, the infants use largely the inferior-forefinger grasp, which, as we have indicated above, is a precarious grasp for infants of this age. Hence, instead of a reduction in the time of grasp from 32 weeks to 36 weeks, we find an actual increase in the time of closure on the cube. At 23 weeks, Watson's infant (62) took two seconds for grasping.

The amount of cube displacement during the grasping act decreases fairly constantly from 20 weeks to 52 weeks, and the number of extra adjustments by the hand before the cube is grasped is one for all groups except for the 40-weeks and 52-weeks infants who require no readjustments for grasping the cube.

Table 19 contains only the data for the first cube situation, because we believe that this situation is best representative of the manner and time of grasping by the infants of the several age groups. We find in the second and third cube situations that the presence of the additional cubes so affects grasping by infants of the several age groups as to make the data, particularly for the third cube, incomparable with the data for the first cube situation.[10]

Method of Lifting the Cube

The investigation into the process of lifting the cube makes no attempt to analyze any movements than those of the arm. We ignore the actions of the trunk, head, and lower limbs, because the conditions of the experi-

[10]Additional data on grasping, and a discussion thereof, are included in the material referred to on page 132.

ment preclude an adequate study of the exact nature of these actions.

Table 20 presents data with regard to the methods of lifting the cube. The first column lists the several means by which the infants raise the cube from the table. The age groups are indicated at the heads of the remaining columns and the figures in the cells of the table denote the number of times the several means of lifting the cube occurred for any of the several age groups.

According to this table, there are several means which infants utilize in raising the cube from the table. A few infants merely rotate the pronated hand inward on its ulnar edge until the palm faces medianward or upward (hand-edge). Some of the younger infants use the shoulder as a fulcrum to swing the entire arm upward. The two commonest forms of lifting from 28 weeks to 52 weeks are those in which elbow flexion functions alone, and those in which rotation on the hand-edge is followed by elbow flexion. A goodly number of infants of the four older age groups (32 weeks to 52 weeks) also resort to simultaneous action by hand-edge and elbow to raise the cube from the table. Lifting by hand-edge followed by shoulder extension, by simultaneous hand-edge–shoulder-extension, occurs very infrequently.

We conclude, then, that lifting by shoulder alone is common only in the younger (20 weeks to 24 weeks) infants, and that lifting by elbow flexion alone or by elbow flexion in conjunction with hand-rotation (hand-edge) are the common forms of raising the cube for infants from 24 weeks to 52 weeks of age.

TABLE 20

Frequency of Occurrence in Each Age Group of the Several Means by Which the Cube Was Raised from the Table

Hand edge signifies that the hand, after grasping the cube, was rotated inward on its ulnar edge, *Elbow* refers to elbow flexion, *Shoulder* signifies shoulder extension. A semicolon between two terms signifies that the two actions referred to occur in sequence, and a dash indicates that the two actions occur simultaneously.

Means by which cube was raised	Age in weeks							
	16	20	24	28	32	36	40	52
Hand edge				3	2		1	2
Elbow			6	7	7	12	7	8
Shoulder		2	4	1	1	1		
Hand; elbow		1	2	6	10	6	8	12
Hand-elbow			1	2	4	7	7	2
Hand; shoulder						1		
Elbow-shoulder								1
Hand-shoulder				1		1	2	2

TABLE 21

Frequency of Occurrence in Each Group of Various Types of Dispositions of the Cube After It Had Been Grasped

All three cube situations included

Types of disposition of the cube	Age in weeks							
	16	20	24	28	32	36	40	52
To mouth			4	9	14	15	11	1
Inspects			3	9	5	11	9	8
Pushes away		5		4		8	4	2
Holds		5	5	13	14	13	10	8
Both hands			1	4	6	9	8	9
Puts down			2	4	9	4	5	14
Drops		1	3	3	4	12	8	1
Picks up			1	3	7	10	9	12
Bangs table		1		1		7	8	9
Other hand			1	3	4	10	9	8
Matches					3	6	4	4
Disregards				1	7	2		3
Fingers cube					1	3	5	3

Disposition of the Cube

After infants grasp the cube they dispose of it in different ways. The 52-weeks infant does not manipulate the cube in the same manner that the 24-weeks infant handles it. We decided, therefore, to determine just how infants of the several age groups dispose of the cube, after they once contact with it, by listing for each infant its activities with the cube.

Table 21 contains the list of these activities and shows that, at 20 weeks, the few infants who secure the cube either push it away or hold it quietly without any further action. At 24 weeks the infants simply hold the cube, bring it to mouth, inspect it, and drop it. At 28 weeks, holding the cube occurs frequently, carrying it to the mouth and inspecting it also occur to a considerable extent. At 32 weeks, holding the cube and carrying it to the mouth are activities of frequent occurrence. These infants often put the cube down, pick it up again, and hold it in both hands. For the three oldest groups the activities are so diversified that none of them are particularly outstanding. However, at 36 weeks, perhaps the most common activities are carrying the cube to the mouth, simply holding the cube, dropping and picking it up again, inspecting it, and exchanging hands on it. At 40 weeks the cube is not brought to the mouth as often as at 36 weeks; holding the cube, inspecting it, dropping and regaining it, exchanging hands on it, and banging the table with it are the outstanding activities. At 52 weeks, manipulation of the cube by the fingers is the outstanding activity. Infants of this age often put the cube down and pick it up, bang

the table, exchange hands on the cube, hold and inspect it.

If we study the table from a different point of view, we discover that up to about 32 weeks of age the outstanding activities with the cube are carrying it to the mouth, simply holding the cube, putting it down, occasionally picking it up, and disregarding it. On the other hand, the table reveals that for the three oldest groups (36 weeks to 52 weeks) there is a decrease in such activities as carrying the cube to the mouth and dropping the cube, and that such activities as holding the cube, inspecting it, exchanging hands on it, bringing both hands to bear on it, putting it down, picking it up, banging the table, matching the cube with the other cubes, and fingering it prevail. Banging the cube against the table not only produces noise for the enjoyment of the infant but also aids him in gaining impressions of weight, hardness, and durability of the object. Holding the cube occurs often in the case of both younger and older groups, but the manner in which infants hold the cube differs greatly. Up to 32 weeks of age the infants hold the cube in the palm of the hand, while infants over 32 weeks of age generally hold the cube with the finger-tips. Again, the younger infants maintain a vice-like grip of the cube, the force of which is wholly out of proportion with the pressure required to hold the cube. The older infants hold the cube with only enough pressure to prevent it from falling. Again, the younger groups, in holding the cube, do not move it about in the hand, while the older groups often change the grip and manipulate the cube about with

their finger-tips. This activity not only aids finer manipulation of the cube, but it also permits better inspection of the cube.

The high sensitivity of the lips is perhaps an outstanding reason as to why young infants always bring objects which they grasp immediately to the mouth. They undoubtedly gain some impressions of the size and form, hardness, softness, smoothness, roughness, etc., from the lips. Now, according to Table 13, the 52-weeks infants seldom bring objects to the mouth within the time of the experiment, but they do inspect and manipulate the cube considerably with the fingers. Perhaps sensitivity of the finger-tips is greater at 52 weeks than at 24 weeks or 32 weeks, and tactual impressions of objects, which these younger infants obtain by means of the lips, are at 52 weeks acquired by means of the finger-tips. Certainly this complete change in the form of activity toward the cube by the 52-weeks infant, as compared with the 28-weeks or 32-weeks infant, and the manner in which the older infant balances the cube on his finger-tips, supports this argument.

Specific Infant Activity

Infants of all ages exhibit a wide variety of activity during the three cube situations. The infants do not direct all these activities toward procuring and manipulating the cube, as we shall see. Table 22 lists most of these activities and shows the number of times that each of these activities occur for the different age groups.

Pianoing is the raising and lowering of the digits alternately on the table, and is nothing more or less than

TABLE 22

FREQUENCY OF OCCURRENCE IN EACH AGE GROUP OF SOME SPECIFIC FORMS OF BEHAVIOR IN THE THREE CUBE SITUATIONS

The meanings of the descriptive terms are explained in the text.

	Age in weeks							
Form of behavior	16	20	24	28	32	36	40	52
Pianoing	5	8	4	1				
Hovering	3	8	1	1				
Rubs table	6	11	4	4	2			1
Doubtful approach	10	2	4	3	1		1	
Scratches table	8	19	7	4	2		1	
Corrals cube	1	3	20	17	7	2		
Hand on table	17	11	6	5	2	1	1	1
Slides hand about	15	2	2	7	2	1		3
Attempts to surround	3	16	7	9	6	9	3	5
Double approach	7	21	14	14	9	18	4	9
Poor direction		4	7	2	1	2	2	1
Double grasp		2	4	3	4	2		
Scooping approach	5	9	16	24	20	11	3	
Bangs table		4	11	10	6	8	16	12
Surrounds cube		4	14	11	11	9	2	8
Poor hand adjustment		3	11	22	13	10	7	3
Overreaches		1	2	7	9	1		1
Underreaches		6	8	15	6	6	3	
Grasps cube		3	15	25	24	30	26	29
Matches cubes				2	5	5	4	7
Exchanges cube			1	6	12	10	8	10

micro-kinetic movements of the digits, which, when *they occur on the table top, resemble the action of the* fingers in playing the piano. Warner (64) and others (17, 65) note that infants while awake exhibit irregular spontaneous movements of the limbs and digits which occur slowly but almost constantly. At 4 months these movements are temporarily inhibited by certain stimuli such as light and sound, at 3 years they are pretty well under control, and at 10 years they are practically gone. Pianoing occurs generally from 16 to 24 weeks. *Hovering,* which refers to suspending the hand motionless above the table for 4.0 or more seconds,

is the end of an incompleted loop approach and occurs often enough at 20 weeks to be noticeable. Rubbing the table with the hand, which includes dragging the hand on the table, occurs generally at 16 and 20 weeks and infrequently at 24 and at 28 weeks. We classify as doubtful those approaches concerning which there is any doubt that they are directed toward the cube. Several doubtful approaches occur at 16 weeks and a few at other ages, particularly among the 20-, 24-, and 28-weeks infants. Infants of 16, 20, and 24 weeks often *scratch the table,* particularly is this true at 20 weeks. *Corralling the cube* means drawing the cube in to get it between the hand and some other portion of the body. Corralling is common at 28 weeks and appears occasionally at 32 weeks. *Hand on table* signifies that one hand at least was not raised from the table during the situation. Sixteen-weeks infants often keep one or both hands on the table throughout the situation. From 20 weeks to 36 weeks the number of infants who do not raise both hands from the table at any time diminishes from 11 to 1. The 16-weeks infants often slide their hands about on the table in contrast to rubbing it, and this behavior occurs infrequently at other ages. *Attempts to surround* indicates that an infant endeavors to get both hands about the cube, and, in case he is successful, we credit him in the column, *Surrounds cube.* Infants of all ages frequently attempt to get both hands about the cube, but this activity appears more strongly at 20 weeks than at any other age. Infants of nearly all ages often reach for the cube with both hands (*double approach.*) The 20-weeks, 24-weeks, 28-weeks, and 36-

weeks infants resort to this form of reaching. *Poor direction* signifies that an infant errs in directing the hand to the cube. We have no record of the errors in direction by the 16-weeks infants because none of them completed an approach. Errors in direction occur in all groups, but most frequently at 20 and 24 weeks. *Double grasps* occur infrequently from 20 to 36 weeks. A *scooping approach* is a very circuitous approach (see Figure 1B), executed on or above the table, in which the hand in executing the broad arc reaches a point beyond the cube, so that in completing the last stage of the approach the infant indicates his purpose of drawing the cube in towards him for the grasp. This type of approach occurs from 16 weeks to 40 weeks but most frequently at 24, 28, and 32 weeks. *Banging the table* occurs from 20 weeks to 52 weeks. The 40-weeks infants lead in this form of activity, but the 52-weeks, 24-weeks, and 28-weeks infants are not far behind. The 24-, 28-, 32-, 36-, and 52-weeks infants frequently surround the cube with hands and forearms. The younger infants sometimes do not adjust their hands well to grasp the cube, either because they misjudge its direction or distance, or because they cannot direct the hand to a favorable position above the cube. If we consider the number of grasps per group, we find that the 20-, 24-, and 28-weeks groups adjust their hands more poorly for the cube than do the older groups. From 28 weeks to 52 weeks the number of *poor adjustments* decreases gradually from 28 to 3. The 28- and 32-weeks groups frequently *overreach* the cube. Overreaching occurs oftenest at these ages because infants

of these two age groups lead in making scooping approaches. *Underreaching*, which signifies that infants make misjudgments of distance so that the hand falls short of the cube, occurs frequently at 20, 24, and 28 weeks. The number of grasps increases rapidly from 20 weeks to 24 weeks and then remains constant for the older age groups. Only the older infants bring cubes together (*match cubes*), as though they were combining the cubes in play. The four older age groups, particularly the 52-weeks group, lead in this combining type of activity. The four older age groups also lead in passing the cube from one hand to the other, i.e., exchanging hands on the cube.[11]

[11]Additional data on these activities are included in the material referred to in footnote 2, page 132.

IV

DISCUSSION AND INTERPRETATION OF RESULTS

The nervous system functions chiefly in response to external stimuli. For this reason special sense-organs are developed on the surface of the body to serve as *receptors for impressions from the environment*, so that they may be transmitted as nervous impulses to the higher centers.

The nervous system develops in a precocious manner and early attains differentiation of function. The direction of this development is toward the periphery, and the two parts, the central nervous system and the peripheral system, appear to myelinate (17) independently of each other (44, 62). Myelination begins in the foetus at about the fourth or fifth month and is not completed until some time after birth (44, 17). The sense-organs generally attain to a high state of efficiency early in post-natal life and develop little thereafter (66). At eight months the brain has doubled its weight at birth, at one year it has increased to two and one-half times the birth weight, and in the third year has tripled it (17). The cerebellum at birth is 6% of the total brain weight and within a month's time it grows to form 10% of this mass (17), thus the cerebellum shows greater energy in post-natal development than does the cerebrum. The former concerns itself with body equilibrium, fine muscular coordinations and adjustments, and muscular tone (44), while the latter utilizes the former in initiating and combining into

harmonious systems and complex actions involving skilled movements (14), such as fine prehension. Therefore, for man, no complicated act can be performed until the centers which initiate and condition that act are fully developed.

Phylogenetically, cerebral and cerebellar development go hand in hand (69). The increase in the size and importance of the cerebellum parallels the increase in the functional control of muscular movements by the cortex. The growth of the former is distinctly a mammalian trait, for, in its development, it takes over new parts such as the area crescens and the pons, which bears the same relation to the two hemispheres of the cerebellum that the corpus callosum bears to the cerebrum, and divides into two lateral lobes, characteristics common only to primates and man. This development involves also the cortico-cerebellar nerve tracts to the area crescens and to the lateral lobes. It is natural to suppose that, inasmuch as the development of this cerebro-cerebellar system came late in man's history, it would be slow in arriving at full maturation in the life of the individual.

Little is known of the exact manner and rate of myelination of specific nerve-fibers of the peripheral and central nervous system from birth to maturity of man. We have, however, the following facts.

The order in which the different parts of the nervous system begin to function appears to favor those sections which are of immediate concern in the infant's welfare. Thus the sympathetic system develops first and then follow in succession the spinal and intracranial ganglia

and reflex centers, the centers for the sense-organs and for complicated motor movements, and finally the centers for expression (17). There is some doubt that the cortex is excitable at birth or that it can exercise inhibiting functions earlier than at one year (17).

Myelination in the cerebral and spinal nerves begins in the motor, and ends in the sensory tracts (17). In the spinal cord the direct cerebellar nerve tract is the first to myelinate, and at birth all the tracts of the cord, with one exception, are fully developed (17). The exception is the pyramidal tract which does not myelinate until about the third month of post-natal life. This delay is undoubtedly due to the fact that its development is contingent upon the functional development of the motor centers of the cortex (17). The portions of the brain which are medullated at birth are the fibers of general sensibility, such as the visceral, muscular, articular, tactile, olfactory, and visual fibers, the thalamus, and parts of the corona radiata, all of which means that the fibers which connect the two hemispheres, the fibers which connect the cortex with the lower central nervous system, and the entire area of the frontal, temporal, and occipital lobes, myelinate sometime in post-natal life (17). Westphal (64, 17) tested children varying from 1 hour to 8 years of age and discovered that infants of 3 weeks of age and younger can tolerate easily an electric current of a strength which adults cannot endure. Among the nerves examined are the ulnaris, radialis, and medianis, the three nerves which contribute to cutaneous, muscular, and articular sensibility in the forearm and hand. Westphal explains that this low ex-

citability is due to incomplete development of the higher centers, and perhaps to the nature of the anatomical structure of the peripheral nerves in which the development of the myelin sheath is slow, gradual, and incomplete for several weeks after birth. Excitability, he says, does not reach its maximum until infants are over 6 weeks of age. Soltmann (53) claims that excitability in sensory nerves of rabbits and puppies increases until they are about 12 weeks old. The inference is that, inasmuch as the human infant matures at a slower rate than the animals cited, the corresponding nerves in man continue to increase in excitability for a time longer than 12 weeks. Other researches (17) also reveal a higher excitability in nerves with increase in age, and Holmes (31, 17), in an investigation of 380 children ranging in age from birth to 13 years, finds that nerves attain adult value in excitability only when children have reached an age of 5 or 6 years.

The order of the appearance of muscular structures is from the trunk out into the limbs (40, 36, 66), and the differentiation of structures of the upper arm precedes that of the forearm, which, in turn, precedes that of the hand (4).

There are three main divisions of the striated muscles, anatomically considered, the axial or longitudinal trunk muscles, the appendicular or limb muscles, which are derived from the former, and the visceral; and, phylogenetically and ontogenetically, the axial muscles precede the appendicular in development (66). The latter are of especial importance to higher vertebrates which depend largely upon their limbs for

their livelihood, and especially to man with his highly developed prehensile organ, the hand. The muscles mostly concerned in arm movements are, in order, the trapezius and latissimum dorsi whose origins are in the trunk, the deltoid, teres major, supra- and infra-spinati, anconeus, triceps, biceps, brachialis, supinator, brachioradialis, and, finally, the muscles of the hand and digits.

The shoulder, with its ball-and-socket joint and splendid array of extrinsic and intrinsic muscles, is a most versatile mechanism. The arm at this point may be abducted, adducted, flexed, extended, and partly rotated, and these separate actions may be combined to give almost any form of movement. The elbow is essentially a hinge joint, but near it are the points of origin of the pronator and supinator muscles which operate to rotate the forearm. The two pronators in the forearm, teres and quadratus, and the two supinators, longus and brevis, act respectively to pronate and supinate the hand. These muscles, combined with the flexibility of the carpal bones and their ligaments, impart to the wrist a freedom of movement almost equal to that of a true ball-and-socket joint. While the joints of the hand concern themselves entirely with extension and flexion of the digits, a system of abductor-adductor muscles spreads and assembles the digits. With the exception of the thumb, there is a double system of flexors for the digits. The first digit is included in one of these systems, and, in addition, is plentifully supplied with individual muscles to aid it in carrying on its repertoire of functions. The surprising feature of hand

structure is the bountiful supply of muscles in the fifth digit. The phylogenetic aspect of this fact has aroused much comment and has influenced the theories of hand development. While the general view is that the little finger is of least help in digital manipulation, it is probable that such inference is not entirely correct. This finger exercises a balancing and steadying influence in writing. The younger infants use this finger and ulnar edge of the hand for supporting and guiding the hand on the slide approach, for setting the digits for grasping, and for the first leverage point in raising objects from the table; hence, the fifth digit undoubtedly aids in steadying the hand, in directing its course, and in adjusting it for gripping and lifting. If the abductor muscles of the fifth digit are not stronger, they certainly respond with greater facility than the abductors of the third and fourth digits. Place only the tip of the fifth digit firmly upon the table and move the other digits about singly or in combination and note the ease, naturalness of movement, and fine adjustments for position and direction which it affords the other digits and hand.

All movements at birth and for some two or three months of post-natal life are of a reflexive type (53, 17). In addition these reflexes are exaggerated in early infancy because the inhibitory centers are not perfectly developed. At three months some control of movements by means of the senses is observable, and at four months a few signs of inhibition are detectable (61, 17). The early shoulder movements of infants, which come under the class of controlled actions, are both

jerkily and slowly performed and are abductive-adductive in character.

An anthropometric table compiled by Crum (13), Assistant Statistician of the Prudential Insurance Co. of America, Newark, N. J., compares the arm lengths of male and female infants ranging in age from 6 months to 24 months.

The table, which represents the average of more than 200 boys and more than 150 girls at each of the ages indicated, shows that arm length increases gradually for both sexes and that the arms of male infants are at each age a trifle longer than the arms of female infants. This table does not include the very youngest infants, but it does give the infant of one year an advantage in reach of more than 1.0 inch over the infant of 6 months, and we are fairly safe in concluding that the advantage is at least 2 inches over the newborn infant.

In comparing the arms of a newborn boy with the right arm of a 3-year-old boy and the arms of 2 men, Heptner (29) concludes that the forearm of the newborn has less musculature, fewer nerves, and more bone

TABLE 23

ARM LENGTH IN INCHES OF MALE AND FEMALE INFANTS VARYING IN AGE FROM 6 MONTHS TO 24 MONTHS

Age in months	Arm length in inches Males	Females
6	10.250	9.875
7	10.625	10.125
8	10.875	10.375
9	11.000	10.750
10	11.250	10.750
11	11.500	11.125
12	11.625	11.250
24	13.500	13.375

than his upper arm. The ratio of the growth in the peripheral nerves of the arm of the 3-year-old to the newborn is 4 to 1, while the ratio of adult nerve growth to the newborn is 15.3 to 1. These facts indicate that development proceeds peripheral-ward, and that peripheral nerves are far from being fully developed at birth.

The first discreet arm movements undoubtly occur as responses to stimuli from within the body, and, as Coghill (12) suggests, are "postural reactions." Later, freedom of movement, as in prehension, is acquired by a gradual "emancipation from postural attitudes." The order of development of the nervous system from the center to the periphery explains not only the early domination of the trunk over the limbs but how it happens that the same motor nerves which at an early period of their development controlled the movements of the muscles of the trunk later extend to the limbs and exercise authority over them (12). Coghill in his investigation of *Amblystoma* regards this primitive animal morphologically as typical of vertebrates (12). The forelimbs of *Amblystoma* develop earlier than the hind limbs and have as their first movements abduction and adduction. Later, as in vertebrate history, the flexor-extensor muscles become effective.

"Behavior," according to Coghill (12), whom we may call a "gestalt" physiologist, "develops from the beginning through the progressive expansion of a perfectly integrated total pattern and the individuation within it of partial patterns which acquire various de-

grees of discreetness." These behavior patterns develop in an orderly sequence which conforms with the development of parts in the nervous system.

The arm behavior of very young infants certainly bears some resemblance to the movements of the forelimbs of *Amblystoma,* as Coghill describes them. In the case of prehension, the very young infant already has the rudiments of a highly integrated nervous mechanism which later governs the refined behavior of the 52-weeks infant; thus, body growth and maturation of the neuromuscular unit involved in the complex act accounts for development of prehension (12).

A study of the mechanics of approach and of grasp shows that prehension in infants progresses along lines which indicate the existence of developmental patterns of reaching, grasping, and manipulation. The patterns, *very loosely combined at first in the young infants,* but manifestly present, develop slowly in an unmistakable and demonstrable manner into highly refined and integrated systems of sequential acts, in which the occurrence of each act of the behavior series is functionally contingent upon those which precede it.

In the act of prehension the body moves as a unit. The infant concentrates the energy of those parts of the body necessary to the act so that they contribute to the one end—the prehension of the object. There may be a shifting or resetting of some of the elements or parts within the total behavior pattern, such as thrusting forward one shoulder (the unilateral urge) instead of bringing the entire upper portion of the trunk closer to the object as do the younger infants, but in either

case there is the integrated system. The fact that older infants rotate the upper trunk instead of lunging forward bilaterally signifies an advance in the maturation of the prehensile neuromusculature.

Why do young infants approach the cube by first carrying the hand out laterally and then swinging it back in the opposite direction toward the medium plane of the body?

Observations on five infants ranging in age from 4 to 20 weeks show that most shoulder movements are those of abduction and adduction, and that infants seldom raise the entire arm and, when they do so, quickly restore it to the platform.[12] In passing, we note that abductive movements are more quickly and vigorously executed than are adductive movements.[13] If we omit instances of emotional strain, all movements of the arm are slow and inclined to be jerky. The fingers are almost constantly in motion (61, 17, 27), and the elbow frequently extends and flexes the forearm in direct opposition to the force of gravity which is, however, at this joint, only one-half as difficult to overcome as that at the shoulder. One does not, of course, expect the arm and hand of the infant of 16 weeks to move in the orthodox manner of the adult forelimb. The individual muscular fibers of newborn infants are about one-third as thick as those of infants one year of age

[12]Dr. Strunk, a member of the staff of the Yale Psycho-Clinic, reports one infant who at 16 weeks held the entire arm aloft from the shoulder for a considerable time.

[13]A sudden emotional upheaval will cause the dorsally placed infant to abduct the arm strongly on a great sweeping arc. Then follows the slow gradual and somewhat intermittent adductive movements which carry the upper arm closer to the trunk.

(17), and it is unlikely that muscular development, in the arms and hands at least, is more rapid in the first few months of post-natal life than in the latter part of the first year, especially in view of the results of this study.

For example, an infant of 12 to 16 weeks, lying dorsally, with arms abducted, in reaching for an object suspended above his chest, adducts the arm at the shoulder as a somewhat inflexible unit. He cannot, or does not, readily flex or extend the elbow, and certainly does not advantageously coordinate its movement with that of the shoulder joint. We do not say the elbow is inflexible but that its movements occur slowly and often jerkily as though it were overcoming resistance from within. The dominance of the abductive-adductive movements and the inability to move the arm fluently contributes to cause the angular, zigzag, sweeping approach movements common in 16- and 20-weeks infants. When the elbow becomes more flexible and cooperates with the shoulder joint in the advance upon the cube, the approach loses its angularity and becomes circular. The refinement of the coordination of these two joints, the gradual elimination of the restraining abductive movements of the shoulder, the ripening of the neuromuscular system of the forearm which governs the mechanics of hand-rotation, and the increasingly greater prominence of the positive actions of the thumb and forefinger account for the gradual transition from the extremely circuitous to the straight approach.

In our opinion there are three main reasons why

movements of abduction and adduction predominate over other shoulder actions in early infantile prehension. First, the direction of the extension of the principal muscles of the shoulder—laterally—contributes to render abductive-adductive movements simpler of performance as compared with movements of extension and flexion. Second, the execution of purely lateral shoulder movements doubtless calls for fewer and simpler muscular coordinations than do movements in other directions.[14] Third, inasmuch as the younger infant spends most of his time in the dorsal position, of all movements which the shoulder performs, the lateral ones least oppose the pull of gravity. In upward thrusts at the shoulder the muscles have to overcome the weight of the entire arm—a not insignificant mass.

We do not sympathize with Bühler's view (8, 34) that learning to grasp depends entirely upon training. A better answer to the problem of prehension is that this form of early learning, as we mention above, de-

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[14]One muscle, the deltoid, perhaps at times aided by the supraspinatus, practically controls abductive movements of the arm at the shoulder. Adduction, which usually occurs slowly, as though the arm were settling back to a position of rest, may be brought about by the pull of any one, or any combination, of these muscles—pectoralis major, teres, major, latissimus dorsi, coracobrachialis, and part of the triceps brachi. In spite of the number of muscles which may be involved in the adductive movement, we still insist it is a simple muscular action because at all times during the course of the movement, the upper arm remains in the lateral plane of the trunk, the plane in which the arm is most at rest, the plane in which no undue tortion of muscles occurs. (Morris' *Human Anatomy*, edited by C. M. Jackson, 6th ed., 1921, 399-416.) With young infants the arm appears to be comfortable when the upper arm is at almost any angle with the trunk as long as the arm remains in the lateral plane.

pends mostly upon growth of the body and the maturation[16] (34) of the neuromuscular system. For example, an intensive course of training for infants from 20 to 24 weeks of age in reaching for a cube will scarcely result in producing a form of approach similar to that of older infants; and how is it possible for an infant with short stubby fingers to grasp and manipulate a cube with a type of grasp resembling the refined grasp of a 52-weeks infant? (See *types of grasp* in this paper.) We incline toward the arguments by Koffka (34) and von Kries (59) that Bühler's theory of training in terms of the formation of sensory and motor bonds requires an enormous number of connections for the completion of any act, simple or complicated, and does not prove the real existence of the bonds which are absolutely essential to the carrying on of the act.

Gesell and Thompson (23), in their co-twin–control study in which they trained one of a pair of twins for a period of six weeks in cube prehension to the exclusion of the other, and compared their behavior patterns before and after the training period, find differences in the twins' behavior with the cubes at the end of the training period to be as slight as the differences exhibited at the start.

The manner in which infants reach for a cube and the type of the ensuing grasp are best explained by the maturation of those parts of his neuromuscular system which control bodily equilibrium and coordination of eye and hand by such anatomical factors as length of arm, hand, and digits.

[16]We use maturation in the sense of ripening tempered by certain inhibitory influences.

The human cerebellum, which attains practically its full size before the fifth year of life, develops rapidly during the first 12 months (40, 44, 34). According to Scammon and Dunn (50), the rapid growth of the cerebellum during the first year of life "is not stimulated by the factors of extra-uterine environment" but "is rather to be regarded as a diminishing residuum" of intra-uterine growth energy. The relation between cerebellar development and the maintenance of bodily equilibrium may be seen from the following observations. Reports of the earliest age at which infants can sit alone vary somewhat. Shinn's infant (52) sits with support at 4 months, suffers an occasional fall at 7 months, and maintains stable equilibrium at 8 months, while Gesell's (20, 21) has unsupported sitting for a short time at 6 months, and for long periods at 9 months. Preyer (52) reports mastery of the sitting act during the eleventh month, Hall (52) at the eighth month, and Feldman (17) gives 8 months as the time when infants can generally sit alone. Watson (63) believes that infants can sit alone at 6 months, Dearborn (15) puts the sitting date at 6 months, Fenton (18) at 4 months, and Jones (32) has 76% of the infants sitting erect at 36 weeks and all sitting at 41 weeks. Concretely, a few infants of 28 weeks sit well for short periods (10 minutes). About all of them do well for short periods at 32 weeks of age, and all sit for long periods (30 minutes) at 36 weeks.

Feldman (17) states that a baby can hold its head erect at 4 months. Miss Shinn's (52) infant masters head equilibrium during the third month, Preyer's

(52) and Gesell's (20) during the fourth month; and, while many of our infants' heads sway at 16 weeks, there is scarcely any swaying at 20 weeks. Kuhlmann (35) uses head balance as one of his tests for the 6-months' level.

It is very likely that the statement by Coghill (12) that the first limb movements of *Amblystoma* depend upon reactions of the trunk applies equally well to infants. At an early age infants will move their bodies in a desired direction even before they are able to extend their arms with any accuracy in overt reaching attempts, or they will stiffen their trunks in resistance to outside forces when they are unable to ward them off by the use of the limbs.

Gesell (21) reports "body reaching movements" for an object within visual range at 16 weeks, closing in on objects held above the infant in the dorsal position, and rolling over to the side. A more mobile and cooperative arm would, perhaps, permit the infant to roll over completely. Shinn (52) has head- and neck-reaching at 12 weeks, and reports little on trunk movements as such. A study of five infants shows that at 12 weeks, while none will close in on a dangled object, they will follow it with their eyes over an arc of 180°. Up to 12 weeks the most vigorous movements are those of the trunk; the head and limbs follow in order. In either the dorsal or prone position, body rotation and propulsion are accomplished principally by throwing the body about or bending or stiffening it. In standing, children sway more than do adults and there is but little increase in steadiness until about the fifth year of life (17).

In the development of approach and of grasp patterns the variably related individual movements of the trunk and limbs undergo many modifications in kind, amount, and sequence before they coordinate to form the perfected act. We find it difficult to regard as random any of the movements of the arms and hands committed during the infant's regard for the cube. The sight of the cube seldom fails to excite increased arm and hand activity of a variety fundamental to the organism from the point of view of service (62). We believe, therefore, that all of the overt attempts by infants which are recorded in this study are directed toward securing, or at least contacting with, the cube. For example, one cannot overlook the changes in the characteristic patterns of approach for the different age groups. The angular sweeping approach of the 16- and 20-weeks infant rounds out into the full spatious circuitous approach of the 28-weeks infant, and this wide detour is succeeded by the slightly curved approach of the 36–40-weeks infants, which later matures into the artistically straight approach of the 52-weeks infant.

There are poorly aimed and poorly directed approaches, but no aimless or directionless ones. An infant of any of these ages advances upon the object of his desire by the only route which he can follow by virtue of the stage of development of his neuromuscular system, and this route is for him, therefore, the most direct approach, be it zigzag, curved, or straight.

All movements are the result of stimulation of some sort, and complicated actions are accompanied by con-

sciousness (47), if one will permit us to use this term. The conscious processes that accompany prehension up to the point of contact are the initiating, the guiding, and the awareness-of-end (47). The types of processes involved in each of the phases of the prehension act are likely to vary not in kind, namely, visual and kinaesthetic, but in their relative amount and combinations, for it is unlikely that either of these senses ceases to function in the sequential unfolding of the total behavior. In the present case, the initiating process consists of visual perception of the cube, accompanied probably by some form of trunk and arm kinaesthesis; the guiding process consists of visual sensations which indicate the position of the object sought, and the visual and kinaesthetic sensations aroused in attaining the successive relative positions of the moving arm and the object; and the awareness-of-the-end process functions somewhere during the act, most likely at the start in the greater number of cases, and probably means possession of the object in whatever forms of consciousness formerly contributed to such import.

One may discourse at length concerning the infant's behavior following his regard for the cube. For some infants of any age all apparent movement ceases for a time and is succeeded either by an attempt to prehend the cube, or a shift of regard to some other object; for some, the course of movement already in progress continues uninterrupted in its course; for others, such movement continues partially interrupted until it gradually comes to a stop; and for others, the movement shifts with scarcely any perceptible change of speed and

but slight change of direction from the object of their present desire to the cube which is then prehended.

An infant's perception of visual space is gained by moving his body about, by extending his arms and legs, by being brought to objects, by reaching for and contacting with them, and by feeling and grasping them—combining the experiences of the visual, cutaneous, and kinaesthetic senses.

Both gross and fine arm and finger movements aid the infant to form judgments of visual space. The infant in his early reaching efforts upon seeing the cube discovers its distance by crude lateral and forward thrusts of the arm and hand. He sweeps the table with his hand and is just as likely to brush the cube out of reach as to corral it. Later, these gross arm and hand actions resolve into the refined movements of the less circuitous and straight approaches, in which the parts of the arm cooperate to introduce fluency into the unfolding of the behavior pattern of reaching. The infant so carefully times the stages in the approach at which successive arm, hand, and finger action occur to eliminate errors in direction and distance, that, in its final form, reaching occurs with a minimal waste of effort and time. Improvement in grasp accompanies refinement of approach; in fact, as we have already pointed out, the two are closely correlated. The more delicate prehensory manipulations which occur when infants finger the cube a great deal, shift it from hand to hand, drop it and grasp it again, inspect it, and subject it to many other manoeuvers, strongly suggest a progressive refinement in perceptions of small volumes

and masses. Some of the crude movements which infants refine or eliminate are: hip flexion without shoulder rotation, shoulder abduction, inflexibility of the joints of the arm, domination of palm in grasping, prominence of medius in approach and in grasp, and thumb immobility. Some of the refinements found in the prehension of 52-weeks infants are: trunk rotation on unilateral approach, arm and shoulder extension forward, improved body and head balance, thumb-opposition, and usurpation by the forefinger of digital leadership.

Vision in infants must be fairly good at 16 weeks, for eye coordination, saccadic pursuit, and coordinate compensatory eye movements apparently function well in the first few days of life (37). Coordination of eye- and head-movements, and ability to shift the regard from one object to another are pretty well established before the sixteenth week (37). The development of eye-hand coordination constitutes one of the most important steps in prehension. A review of the literature shows that voluntary reaching for objects by infants appears to start about the fourth month. Warner (61, 17) notices that control of movement by means of the senses occurs at 3 months and that indications of inhibited behavior appear at 4 months. Watson (62) reports a questionable effort to reach for candy suspended before an infant at 101 days, a positive grasping at the candy on the 122nd day, and the disappearance of the grasping reflex by the 136th day. On the 171st day coordination of eye and hand is well fixed. Shinn (52) reports groping for objects at 16 weeks for both

her infant and Moore's infant, and grasping for objects visually located at the 11th week for Hall, 12th week for Moore, 17th week for Shinn and for Preyer, and the 26th week for Sully. Preyer's infant at 17 weeks grasps at objects out of reach and at 18 weeks reaches too short for objects (45). Gesell's infants at 4 months reach for and grasp objects in both dorsal and sitting positions (21). They regard a cube at 4 months but disregard a much smaller object, a pellet; at 6 months the infant grasps the cube and regards the pellet. Koffka (34) calls our attention to the fact that Shinn's baby at 3 months does not make "definite hand and arm movements, but is merely uniting hand and mouth." Our study shows that at 16 weeks two-thirds of the infants (8 of 12) make positive attempts to secure objects from a table before them, but that they cannot be expected to grasp them, even at a distance of only 3.0 inches.

Our investigation discloses that there is a gradual emancipation of the digits from the hand, of which no member at birth has specialized functions. To better understand this development we present briefly the following facts. The sensibility of the palm of the hand of a newborn infant is not as great as that of the lips and mucous membrane of the nose, according to Preyer (45) and Canestrini (10) and his latent period of tactual sensibility is longer than that of the adult. A number of investigators (17, 45, 64, 10, 65, 53) have shown that for some weeks of post-natal life the infant has low sensibility to pain, and it is likely that the pressure (tactile) sense is not highly developed until some weeks

after birth. Camerer (9), experimenting on individuals ranging from 3 years to adulthood, finds that sensibility of the arm in general increases with age. Infants begin to feel about with their hands at about the 12th week, to watch their fingers from about the 15th to the 23d weeks of life (52) (a fact that this investigation also reveals), and to hand objects (52) instead of putting them into the mouth at the 21st week. The grasping reflex, an action involving the undifferentiated hand, disappears at about 20 weeks (62), and reaching begins at about 17 or 19 weeks (52). The striped muscles, which must be considered in accounting for prehension, have a low excitability (65, 17) for the first two or three months of life. These conclusions tend to indicate that the several digits of the hand only slowly become individualized out of the whole "paw," and that differentiation of digital functions does not occur until after 24 weeks of life.

Young children do not hold hands still nor keep the index finger quiet for 30.0 seconds at a time until they are 5 or 6 years old (17). Our infants at 16 and 20 weeks occupy a considerable portion of their time in scratching, rubbing, or pianoing the table, and in regarding their fingers as they draw the hand in across the table surface. Exploring the cube with the finger-tips becomes an active form of behavior after 24 weeks.

Why does the infant reach for and seize objects with the hand? The answer seems to be that he wants it, not only for the sole purpose of possession, but perhaps that he may better appreciate it. For, as we have pointed out, certainly no portion of the body is better

equipped with end-organs to render information of an immediate nature of the prehended object. The fact that the younger infants so often bring the object to the sensitive lips lends substantiation to this view.

Why do infants from 16 to 28 weeks of age hold the cube by pressing it into the palm, while older infants hold the cube between the thumb and the two nearest fingers? Freedom of manipulation of the object, rather than certainty of grip, favors the latter form of grasp, but is it not within the range of probability that the anatomical structures fundamental to the mechanics of grasp are undergoing a change which for the older infants favors the application of the tips of the digits instead of the palm? Is it not likely that the preferential use of the finger-tips, which involves cooperation of the "opposed thumb" in grasping, in place of the palm grip, is an indication of the maturation of those portions of the peripheral nervous system which function both affectively and effectively in the digits?

Young infants from birth to 6 months exhibit a grasp of a force entirely disproportionate with the pressure necessary to hold and lift the seized object. Whether the object be heavy or light, it is driven hard against the palm in a vice-like palm grip which is purely an expediency for procuring and holding the object. As the age of the infant increases, the force of the grip diminishes, until at 52 weeks he takes the cube with the finger-tips in a manner which suggests the presence of some appreciation of the amount of pressure required to lift and hold the cube. The infant now desires not only to procure the cube but to explore it. Is the object hard

or soft, rough or smooth, heavy or light, et cetera? It is exceedingly doubtful that the earlier vice-like grips are intended to give this information.

Here, then, we have an excellent example of the *development of perception—beginning with an infant for* whom the relation of the force of grip to the mass of an object means nothing, and ending with the infant who adjusts the pressure of his grip with little or no waste of energy to suit the weight and shape of the object. In this development the gradual lessening of the force in gripping corresponds closely with the shift of the object from palm to digit-tips in grasping.

Prehending the object with the tips of the digits is then an act of economy as well as an act of skill. The infant, by means of the forefinger grasp, enjoys possession of the object, manipulatory ease and fluency, and the advantage of a highly sensitive skin surface (see page 114) of considerable informatory value to the in*dividual.*

It is likely that the length of the digits, and the degree of cooperation of the kinaesthetic and pressure sensations with the neuromuscular system of the forearm and hand, determine the type of grasp which an infant applies to an object of a given size, form, and mass, such as a cube. Of course, the older infants have longer digits than have the younger infants. We have already shown[10] that in adults the finger-tips are especially sensitive to pressure, although we are uncertain as to just when the end-organs for pressure are functionally mature. We suspect that at 16 weeks the end-organs

[10]See "Introduction," page 114.

for the pressure and for the kinaesthetic senses and the neuromuscular system of the arm and hand are not developed to the extent that they are at 52 weeks, although there is some evidence that tactual sensibility is high in young children (17). There must be a time in infancy, however, when these prehensile determinants ripen relatively rapidly to produce the changes we find in grasp, and we strongly suspect that this maturation begins sometime after the fourth month of life.

From our investigation we know that thumb-opposition takes definite form from 28 to 32 weeks, although some attempts are made to secure grasps of this type at earlier times. Some experiments (15, 43, 18, 52) appear to indicate that thumb-opposition occurs at about the 12th week, while others (35, 20) place it at 6 months. Shinn (52) notices the tendency for the thumb to reverse during the 9th week, Preyer (45) notices it at the 14th week, and Jones (32) records opposition in 50% of her cases at 148 days, and in 100% of her cases at 266 days.

Twelve weeks is an early age for the appearance of this form of behavior, according to our data. Naturally, the sort of object used influences grasp. A certain type of thumb-opposition will come into play more easily if a long, slender object is placed in an infant's hand, than if a thick block is similarly used. A true test of opposition, it seems to us, is furnished in prehension of a cube, for there seems little doubt that it is only in grasping an object of some considerable diameter that we can be certain that the thumb is actually oriented to secure the higher type of grasp. A long, slender object

will more easily permit accidental opposition of the thumb, as in Preyer's case where the object used is a pencil.

We have conducted a number of experiments lately on infants of 4, 8, 12, 16, and 20 weeks, who are placed dorsally, to see how they prehend slender rods and 1.0-inch cubes. These infants never grasp the cube with thumb-opposition, but all succeed in getting the thumb about the rod in opposition to the fingers. Even at 4 weeks it is as likely to be in opposition as not, depending on whether the examiner favors such opposition by the way in which she places the rod in the infant's hand. However, the type of opposition which the infant exhibits in grasping the rod is purely passive, and is not to be confused with the type of thumb-opposition that he displays in voluntarily grasping a cube. The latter thumb action is positive, in that the thumb is definitely oriented to cause its palmar surface to face that of the forefinger. Passive thumb-opposition occurs only in grasping such objects as pencils and slender rods; such opposition fails in the prehension of objects of any considerable thickness, as a cube.

Infants of 16 to 24 weeks afford excellent examples of what is apparently thumb-opposition by the manner in which they approach the cube. They hold the hand fully pronated with the thumb pointing or hanging down so that we get an impression of opposition. However, what looks like opposition does not carry through, for we find that this form of approach usually precedes a squeeze or hand grasp, while the form of approach which leads to genuine opposition finds the thumb en-

ergetically pointed pretty well in horizontally toward the median plane of the infant. In the earlier approach the thumb appears as an extra and almost unnecessary appendage to the hand, which, in approaching the cube, betrays no individual digital proclivities, while in the more mature approach the thumb and the forefinger specialize to direct the course of the approach.

Jones (32) has the best controlled experiment on reaching. The infant who is lying dorsally is given 10.0 seconds to prehend a "bright toy" which is moved toward him on a line between the eyes. At 27 weeks, 92% of the infants are successful and at 33 weeks all infants are successful in acquiring the object. Under our experimental conditions 38% of the infants secure the cube at 24 weeks, 92% at 28 weeks, 92% at 32 weeks, and 92% at 36 weeks. The only reason infants fail at the two latter ages is because they desire to play with the cube rather than grasp it. Gesell (21) varies the procedure with the age of the infants and finds reaching for a spoon is direct and accurate at 6 months. Kuhlmann (35) dangles objects before the eyes of the infant and watches for speed and success in reaching the object.

Jones finds thumb-opposition for the first time at 15 weeks with a cube of the same size as ours. We have one instance of opposition at 20 weeks, 7 cases at 24 weeks, and 19 cases at 28 weeks. The difference between Jones' results (32) and our findings consists in the method of presentation, for Jones puts the cube into the hand, while we permit the infant a free hand in prehension.

TABLE 23a

PERCENTAGE OF THUMB OPPOSITION IN GRASPING CUBES IN JONES'S EXPERIMENT AND IN OUR EXPERIMENT FOR INFANTS RANGING IN AGE FROM 16 WEEKS TO 40 WEEKS

Age (weeks)	Percentage of thumb opposition Jones's	Ours
16	10	0
20	41	33
24	73	47
28	84	73
32	80	87
36	94	90
40	100	96

In this connection we find that for infants up to 32 weeks of age the nature of the grasp is determined by the manner in which the digits come to rest upon the cube, for these infants, regardless of the precariousness of their hold, do not adjust and readjust the hand to obtain a more substantial grasp. They maintain their original grip, be it ever so frail, until the cube falls or slips away. In placing the cube in the hand, we wonder whether it was put into the middle of the palm where thumb-opposition is unlikely to occur, or into the palm nearer the thumb, a position which favors opposition. Jones's results (32), however, are in close agreement with ours, for between the ages of 30 to 36 weeks active thumb-opposition is practically fully developed (80% to 90% of her cases), while at 32 weeks 87½% of our grasps are of this order (see Table 23*a*).

Our results show that thumb-opposition to the fingers does not appear in the grasp to any extent until the infant is 28 weeks old, while Preyer (45) admits that thumb-opposition at 22 weeks is often missing. Up to 28 weeks, the thumb action consists mainly in adduc-

tive-abductive movements with a small amount of extension and flexion. At 16, 20, and 24 weeks, the hand, during the approach, is usually fully pronated, with the thumb either pointing or hanging down rather inactively or even curled under the palm; and in the act of grasping we find that the thumb extends at full length along the lateral face of the cube adjacent to the forefinger. The thumb appears to have no prehensile significance unless it may be to prevent an object, not too securely held, from slipping away through the opening at the radial side of the fist. Indeed, its position in grasping resembles closely that of the quiescent thumb, as illustrated by Wood Jones (68) in the hand at rest. In other words, before 28 weeks, the thumb of the infant is the least active of the 5 digits, not excepting the little digits which synchronize with the other fingers in grasping and manipulating objects.

The story of prehension is in effect a story of the thumb. This study reveals that the improvement in type of grasp corresponds closely with the gradually increasing activity of the first digit. There is no accelerated development in the process of grasping; there is merely a ripening of the forces that go to insure a safe grasp as the object finds itself advancing progressively and regularly from mid-palm to radial edge of palm and then out to the tips of the thumb and its two adjacent fingers. Just as long as the thumb remains quiescent, the infant, in order to hold the cube, finds himself compelled to envelop it by the fingers and to drive it firmly into the palm, so that the heel of the palm may provide opposition to finger pressure, which opposition

later will be supplied by the thumb. At 28 weeks, when the thumb starts to assert itself in grasp, several interesting incidents occur which reveal the unreadiness or immaturity of the thumb to function perfectly. (*a*) We have instances of the thumb actually contacting momentarily with the cube in opposition to the fingers and then slipping off to the adjacent side as closure continues. (*b*) We often find the thumb pressed against the near face as in the finished form of grasp. In both these cases we may attribute the failure of opposition to the inability of the infant to sufficiently swing the thumb about on its axis to a point essential to complete opposition. (*c*) The infant sometimes brings the other hand into play to aid the prehending hand to hold its cube. The two types of palm grasp in which thumb-opposition first occurs may be regarded as the stage in which the infant awakens to the fact that not only may the hands be used to grasp and hold an object, and perhaps carry it to the mouth, but to render knowledge of the prehended object and to serve as manipulatory organs in handling the object so that other senses may be brought to bear upon it to add to such knowledge.

Abduction and adduction of the thumb are simpler functions than are movements of opposition (60). Abduction is principally the function of one muscle, the abductor pollicis longus, although it may be aided in part by the abductor policis brevis and the extensor pollicis brevis,[17] all of which, however, in producing ab-

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[17]Wood Jones (68) states that the absolute "differentiation of the extensor pollicis brevis from the abductor pollicis longus" distinguishes "the thumb of man from that of any of the anthropoids."

duction operate in practically one line. Adduction, likewise, is mainly the function of the adductor pollicis aided by the opponens pollicis and flexor pollicis brevis.

Opposition to the fingers by the thumb is generally explained as the function of one muscle—the opponens. Walsh (60), who has made a special study of the anatomy and physiology of the muscles of the hand, takes issue with this view and ascribes the action of opposition by the thumb to the co-joint functioning of three muscles or tendons, namely, the abductor pollicis brevis, the flexor pollicis brevis, and the opponens pollicis. The abductor pollicis brevis, with its origin in the ligaments and bones of the wrist and its insertion in the radial side of the base of the first phalanx of the thumb (44) and in the aponeurosis of the extensor pollicis longus, extends the second phalanx on the first and the first phalanx on the metacarpal bone, moves them out laterally, and then flexes the metacarpal bone also in this same direction. The flexor pollicis brevis, with its origin also in the region of the wrist and its insertion partly in the radial side, and partly in the inner half of the anterior side, and partly in the whole of the ulnar surface of the base of the first phalanx, extends the second phalanx on the first, flexes the first phalanx on the metacarpal bone, and finally flexes the latter. The opponens has its origin in the carpal bones and their ligaments and its insertion in both the radial edge and in the anterior surface of the first metacarpal bone. This muscle rotates the metacarpal bone on its long axis and flexes it. The combined action of these three muscles brings the thumb about in a way which places

its volar surface in opposition to the volar surface of the forefinger.

Now it is our contention that, inasmuch as abductive-adductive thumb movements are relatively simple to perform—actions which may be brought about through the functioning of a single muscle—they will be among the first movements of the thumb in the early life of the infant; and, because thumb-opposition is a relatively complex act which involves the combined simultaneous action of parts of three distinct muscles cooperating in a manner which suggests that they develop only after several weeks of post-natal life, such thumb action will appear relatively late in the life of the infant.

The functional development of the forefinger parallels that of the thumb. The younger infants for whom the thumb acts in a purely passive manner point their hands at the cube in reaching for it so that the hand has the appearance of a paw in which the medius appears to lead in directing the course of approach. When the thumb develops to the point at which it exhibits active opposition in grasping, the forefinger assumes leadership over the digits in directing the approach. The infant, instead of projecting the entire hand so that the palm, on nearing the cube, may descend full upon the cube, now thrusts the hand forward so that the forefinger only will pass directly above the cube. This balanced functional development of the thumb and forefinger is most fortunate for the individual, because the forefinger, more than any other finger is most concerned in meeting the conditions of opposition by the thumb in the prehension of objects.

For example, in infants of 52 weeks the thumb and forefinger alone provide the opposition in the grasp of small objects, such as a pellet. When the infant prehends slightly larger objects than the pellet, the medius aids the forefinger in opposition, and the thumb shifts ulnar-ward to balance the joint pressure of these fingers. Thus, as objects become larger, the infant utilizes additional fingers to assist the forefinger in meeting the opposition by the thumb, which in turn shifts farther and farther ulnar-ward to balance the resultant force of the pressures of the individual fingers applied at different points on the object. The forefinger and thumb then are the leading digits of the hand in mature prehensory manipulation. According to Wood Jones (68), only in man does the forefinger stand "aloof from its fellows" and function as a specialized organ.

The crease lines of the hand permit freedom in flexure in cupping the hand for grasping. The distal pad of the palm extends the greater part of an inch beyond the metacarpo-phalangeal joints and this overlapping of the palm on the proximal phalanges of the fingers accounts for the deep crease in the palm opposite these joints, which allows the palmar surface to double on itself to decrease its extent. The papillary ridges of the palm and of the volar surface of the digits also function in grasping. The arrangement and distribution of these ridges give the volar surface of the hand the appearance of a broad, fine file and provide a gripping surface difficult of improvement. In passing, we do not overlook the fact that man often utilizes the nails of the digits in picking up tiny objects as pins, and in

scratching. The nails also strengthen and brace the finger-tips in rubbing surfaces, and in grasping objects, such as cubes.

V

CONCLUSIONS

1. There are four steps in prehension: (*a*) the visual location of the object, (*b*) the approach by the hand, (*c*) the grasp, and (*d*) the disposal of the object.

2. The amount of regard by the infants for the cube increases rapidly from 4.75 seconds at 16 weeks to 18.0 seconds at 28 weeks, and then generally decreases to 10.75 seconds at 52 weeks. The fact that the older infants grasp the cube sooner than the younger groups (less than 32 weeks of age) may account for this decrease in time. The group medians for the average duration of the individual regards for the cube, for the longest regard, and for the first regard, follow the same general rule for rise and decline of time values as does the total regard time.

3. Infants of the 16-weeks group and of the 20-weeks group usually follow the short initial regard for the cube with a second, and sometimes a third, brief regard. The other infants vary greatly in their manner of regard; some infants attend the cube throughout the duration of the situation, others regard it briefly several times, others regard it profoundly twice or three times, and some look at it but once.

4. Only slight differences distinguish the regard for the second cube from the regard for the first cube. At 36 weeks and at 40 weeks the duration of the first regard for the second cube is greater than the duration of the first regard for the first cube. This increase in regard is due to delayed reaching for the cube, which,

in turn, is due to interference caused by the presence of a cube already in the infant's possession. For the remaining groups, the first regard for the second cube is as short as that for the first cube. The brevity of the first regard is marked at 52 weeks, for these infants secure the cube quickly and look elsewhere immediately. A number of these infants grasp the cube without looking at it.

5. In the third cube situation the total regard for the cube for the five lower age groups is less than that for the first and for the second cubes, but for the 36-, 40-, and 52-weeks infants there is no difference in total regard. The presence of two cubes in the infant's hands apparently interferes with his regard for the third cube. In contrast to what we find in the first and second cube situations, there are no long regards for the third cube in any of the groups.

6. The sequence of infants' regard for objects about them varies for the three situations. The 16-weeks infants first regard the presented cube, then the table top or their hands (in fact, it is sometimes difficult to tell when it is one or the other, particularly when they scratch the table), and then the cube or the examiner. The 20-weeks group regard first the cube, then the examiner, and then the cube again, or the other cubes if they are present. The remaining age groups in the first situation first look at the presented cube, then at the examiner or the dome, and then again at the cube. In the second and third cube situations the regard goes to the presented cube, then to the other cubes or the dome, and then back to the cube.

7. The arrangement of the groups with respect to frequency of shifts of regard, beginning with the group having the greatest number of shifts, are: 36-weeks, 20-weeks, 52-weeks, 40-weeks, 16-weeks, 24-weeks, 32-weeks, and 28-weeks.

8. All infants regard the presented cube longer than they regard any other object. Interest in the other cubes waxes from 16 to 28 weeks and then weakens gradually with age. Only the 16-weeks and 20-weeks groups regard at length the hands and table. At 16 weeks infants regard the examiner extensively. There is then a gradual and rapid decrease in the amount of regard for the examiner, until at 28 weeks infants scarcely notice her. The older infants regard her infrequently. The 52-weeks infants regard the dome longer than do those of any other group, the 32-weeks group also look about them at length, while the 24-weeks group regard the dome but little.

9. After 24 weeks, the infant's first approach is likely to yield success in reaching the cube. Speed in reaching increases with age up to 32 weeks and then decreases. Bilateral approaches appear frequently at 24, 28, and 32 weeks when both hands are unburdened with other cubes.

10. Infants regard the presented cube most frequently. After this cube, the objects oftenest regarded are: at 16 weeks, the table and examiner; at 20 weeks, the examiner and the dome; at 24, 28, 32, 36, and 40 weeks, the other cubes and the dome; and at 52 weeks, the dome and the examiner.

11. Three forms of approach appear: the backhand

sweep; the circuitous, which includes, besides the angular and scooping sweeps, the less circuitous reaching; and the direct (straight) approaches. Infants from 16 weeks to 28 weeks of age employ either the backhand approach, which is only the first half of the circuitous approach, or the very circuitous approach in reaching. Infants of 32 and 36 weeks use a less circuitous form of approach in reaching for the cube, and infants of 40 and 52 weeks usually employ the direct approach. Genetically, the backhand and circuitous approaches straighten out into the direct approach. Up to 24 weeks of age, the infants in reaching usually point the hand so that it will come to rest fully upon the cube. After 28 weeks, they so direct their hand that only the forefinger will pass over the mid-top of the cube.

12. The lateral view of reaching reveals three principal types of approach: (*a*) the slide, which is extensively employed by infants up to 32 weeks of age, (*b*) the loop, which likewise is employed by these younger infants whenever they do not use the slide approach, and (*c*) the planing approach, which is the characteristic reaching action of infants of 36 to 52 weeks of age. Combinations of these profiles also appear, such as the loop-slide, the plane-slide, and the plane-loop.

13. The unilateral approach is the common type of reaching at all ages, but bilateral approaches are about as common as the unilateral type at 24 weeks, and occur frequently at 20 weeks.

14. Up to 28 weeks of age infants raise their hands relatively high in reaching for the cube. From 28

weeks to 52 weeks the height of the approach gradually diminishes.

15. There are four adjustment stages in the approach pattern: (*a*) The *initial advance.* (*b*) In the *accelerated advance* the hand increases its speed forward and generally laterally, although the destination of the hand is as yet indeterminable. (*c*) In the next stage, *alignment,* the hand points so that its ultimate destination is no longer a matter of conjecture, for the cube is within that portion of the table top which subtends the thumb-forefinger angle. (*d*) The *culminating approach*, in which the hand sets itself for the grasp, follows the aligning approach.

16. From 16 weeks to 24 weeks, infants often raise the hand, thrust it forward circuitously, and lower it in a manner which suggests that the approach consists of three individual acts. At 40 weeks, no trace of these separate acts is discernible; they are incorporated into one fluent reaching movement.

17. If we except those approaches which cut in short of the cube, infants from 16 weeks to 28 weeks of age point their forearms directly above the cube at the final stage of the approach, and, while infants over 28 weeks of age sometimes direct the forearm in this manner, they usually aim it toward a point above the lateral side of the cube which is nearest the reaching hand.

18. Infants up to 28 weeks of age reach for the cube with the thumb pointing almost straight down from a pronated hand, and the older infants approach the cube with the thumb directed in median-ward or semi-median-ward from a hand which is slightly rotated in the same direction.

19. The manner in which infants hold the thumb in reaching indicates roughly the kind of grasp which follows. If the thumb points inward, the grasp will find the thumb opposed to the fingers; if the thumb hangs down or curls under the palm, a grasp of lower order will result.

20. For the youngest infants the plane of the angle formed by the forefinger and thumb just preceding grasp is vertical. As the infant matures, the plane of this angle rotates toward a horizontal line.

21. In reaching for the cube, the hand usually remains pronated throughout its entire course, or it rotates slightly from a somewhat palm-in toward a pronated state as it sweeps in toward the cube. During the approach, the other hand usually does not rotate, regardless of its other movements.

22. Accuracy in reaching by infants improves gradually and steadily from 16 weeks to 52 weeks.

23. At 16 weeks no infants are likely to touch the cube. At 20 weeks one-fourth of the infants touch the cube, and one-third grasp it crudely. At 24 weeks about one-half of them touch, and one-half grasp the cube. At 28, 32, 36, 40, and 52 weeks we may expect all infants to grasp the cube, if they really desire it. The distinguishing differences between these older infants is in the time actually required to grasp the cube, amount of cube displacement, number of adjustments necessary for a firm grasp, and the type of grasp.

24. There are ten types of grasp which arrange themselves in a genetic series: (*a*) no contact, (*b*) contact, (*c*) the primitive squeeze, (*d*) the squeeze grasp,

(*e*) the hand grasp, (*f*) the palm grasp, (*g*) the superior-palm grasp, (*h*) the inferior-forefinger grasp, (*i*) the forefinger grasp, and (*j*) the superior-forefinger grasp.

25. The type of grasp determines the aim of the approach. The infant points his forearm directly at or above the cube to secure a palm grip, and he points his forearm at or above the near lateral face of the cube to procure a forefinger grasp.

26. Older infants grasp the cube sooner after its presentation and, after touching it, secure a firm grip more quickly than do the younger infants. The former also make fewer adjustments, and displace the cube less in grasping it, and regard it less both before and after grasp.

27. Infants from 16 to 28 weeks of age seldom grasp the cube from the *S.M.* position, while the older infants usually grasp it from this point. If we except the 16-weeks infants, who never grasp the cube, we find in general that the number of unsuccessful attempts to reach the cube varies inversely with the age of the infants. The 24-weeks group touch the cube oftenest without grasping it, and the number of grasps increases with age up to 28 weeks, after which the cube is usually grasped by all infants except when other cubes are present. No age group demonstrates clearly that one hand is preferred over the other in the prehension of the cubes.

28. Twenty-eight weeks is the critical age in infant prehension. Infants at this age have the longest single regard and the greatest total duration of regard for the

cube. The hand begins to free itself from forearm control in reaching for objects. Corralling is giving way to direct reaching, and the infant, instead of directing the entire hand toward the cube, is beginning to point his hand so that only the index and medius fingers will pass over the cube. The hand is losing its paw-like behavior in favor of finger manipulation of the cube, and a vital change from palm grip to active thumb opposition is occurring in the type of grasp.

29. Infants often reach for and touch, and three of the older ones grasp, the presented cube when they already hold a cube in the approach-hand.

30. Up to 28 weeks of age the infant often invokes the aid of the second hand in grasping.

31. Infants contact oftener with the third cube than with the second cube but they do not grasp the third cube nearly as often as they grasp the second cube.

32. Active thumb-opposition, which occurs only in the higher types of grasp, is a complex act which involves the coordinated action of three muscles and therefore appears relatively late in infancy.

33. The delay in the digital leadership of the forefinger is perhaps due to the late maturation of its neuromusculature.

34. The two most common forms of lifting the cube from the table are: (*a*) a purely elbow flexion and (*b*) a hand-elbow action, in which the hand, after grasping the cube, rotates on its ulnar edge before elbow flexion begins.

35. The more characteristic reactions to the cube by the infants of different ages are as follows: At 16

weeks, infants follow the examiner's hand after she presents the cube, slide their hands about on the table, and often keep one or both hands on the table during the entire situation. At 20 weeks, infants scratch the table, and attempt to get both hands about the cube after reaching with both hands simultaneously. If they succeed in touching the cube, they either push it out of reach or simply hold it. At 24 and at 28 weeks, they approach the cube in a scooping manner, sometimes using both hands, and then corral and surround the cube or push it out of reach. After grasping the cube, they hold it, take it to the mouth, inspect the cube, and release and regain it. At 32 weeks, the infants use the scooping approach to surround the cube, inspect it, take it to the mouth, release and pick the cube up again, and exchange it from one hand to the other. They often disregard the cube when there are other cubes present. At 36 weeks and at 40 weeks, the infants execute a number of bilateral approaches and shift the cube from one hand to the other. They also bring the cube to the mouth, simply hold the cube, inspect it, hold it with both hands, release and regain it, bang the table with it, exchange hands on it, execute a number of bilateral approaches, and hold it in both hands. The 52-weeks infants often put the cube down and pick it up again, bang the table, exchange hands on the cube, simply hold it with one hand or both hands and inspect it, but do not bring it to the mouth. The 16-weeks infants do not, as a rule, reach the cube.

36. From 16 to 36 weeks the range of activity of infants' hands on or above the table top gradually in-

creases. From 36 weeks to 52 weeks the activity decreases slightly.

37. Prehension in infants progresses in a manner which indicates the presence of developmental behavior patterns. These patterns, which in early infancy appear as very crude forms of reaching, grasping, and manipulation, develop gradually and observably into highly refined and integrated systems of sequential acts.

38. The development of reaching and grasping affords excellent examples of the progress of maturation from the coarser to the finer muscles. The early approach patterns consist largely of crude shoulder and elbow movements in which slow and somewhat angular action predominates, while the later approach patterns employ better directed shoulder and elbow action, in addition to wrist movements and hand-rotation, under the dominating influence of the forefinger and thumb. The early approach reveals a crudely functioning hand at the end of a poorly directed arm, while the later approach reveals a well coordinated arm under the directing influence of a pretty well developed prehensile organ. In grasping we find at first a clawing type of closure in which the thumb is practically inactive and no digits predominate, succeeded by a nipping, pressing type of closure the dominating factors of which are the thumb and forefinger, i.e., a crude palming movement giving way to a refined forefinger-tip grasp which includes precise placement of the digits upon the cube.

39. The increase in the number of higher types of grasp and the increase in the amount and variety of

digital manipulation of the cube in infants from 16 to 52 weeks of age are due in part to anatomical growth of the digits of the hand, in part to maturation of its neuromusculature, in part to training, and in part, perhaps, to increase in cutaneous sensibility of the finger-tips.

40. This investigation demonstrates the applicability of the motion camera for the study of infant behavior.

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UNE ÉTUDE EXPÉRIMENTALE DE LA PRÉHENSION CHEZ LES ENFANTS EN BAS AGE AU MOYEN DE NOTATIONS CINÉMATOGRAPHIQUES SYSTÉMATIQUES

(Résumé)

Cette étude est une analyse des notations cinématographiques, en mouvement et aussi chaque cliché considéré par lui-même, de la préhension des cubes d'un pouce à chaque côté par des enfants en bas âge. L'étude se sert de quelques techniques photographiques pour analyser et résoudre le comportement humain en des formes de temps et d'espace. Les sujets ont été douze ou plus enfants âgés de 16, 20, 24, 28, 32, 36, 40, et de 52 semaines. Il y a quatre stades dans la préhension: (1) Celui où l'on trouve l'objet visuellement, (2) celui où l'on étend la main vers lui, (3) celui où on le saisit, et (4) celui où on le manipule. Une vue d'en haut montre trois formes d'étendre la main. L'ordre de leur apparence chez les enfants des âges cités ci-dessus est le suivant: (1) La courbe, la main tournée en arrière, (2) l'approche indirecte, qui inclut (a) la courbe latérale, la main tournée en arrière suivie d'un mouvement de retour dans la direction opposée, (b) l'approche très indirecte à la manière d'un écope, et (c) l'approche un peu indirecte, et (3) l'approche directe. Une vue latérale montre que les très jeunes enfants étendent la main pour les objets ou en faisant glisser la main sur la table ou en levant et baissant la main de sorte qu'elle décrit un arc. Les enfants plus âgés étendent la main "en planant" vers le cube. Il y a quatre stades d'ajustement dans cette action d'étendre la main: (1) l'avance initiale, (2) l'avance accélérée, où la main augmente sa vitesse en avant, bien que la destination de la main ne soit pas encore déterminable, (3) le stade d'alignement, où la main s'étend de sorte que sa vraie destination est tout à fait claire, et (4) le dernier stade, où la main prend la position de préhension. *La manière dont un enfant tient le pouce en étendant la main indique quelque peu la manière dont il saisira le cube. Si le pouce s'étend en dedans, l'enfant saisira* le cube de *sorte que* le pouce s'opposera aux doigts; si le pouce s'opposera aux doigts; si le pouce s'incline en bas ou se courbe sous la paume, l'enfant saisira le cube sans l'opposition du pouce. Le développement des actions d'étendre la main et de saisir donne d'excellents exemples du progrés de la maturation des muscles grossiers à ceux qui sont plus fins. La première approche montre une main qui fonctionne grossiérement au bout d'un bras mal dirigé, tandis que la dernière approche montre un bras bien coordiné sous l'influence directrice d'un organe préhenseur assez bien développé. Dans la préhension on trouve d'abord un type qui ressemble aux griffes, où le pouce est un général inactif et où aucuns doigts ne prédominent, suivi d'un type qui pince et serre, où les facteurs dominants sont le pouce et l'index. Il y a dix types de préhension lesquels se rangent en suite génétique: (1) Nul contact, (2) le contact, (3) l'action primitive de serrer, (4) la préhension au moyen de serrer, (5) la préhension au moyen de la main, (6) la préhension au moyen de la paume, (7) la préhension supérieure au moyen de la paume, (8) la préhension inférieure au moyen de l'index, (9) la préhension au moyen de l'index, et (10) la préhension supérieure au moyen de l'index.

HALVERSON

EINE EXPERIMENTELLE UNTERSUCHUNG DES FASSENS (PREHENSION) BEI SAEUGLINGEN MITTELS SYSTEMATISCHER KINEMATOGRAPHISCHER REGISTRIERUNGEN

(Referat)

In dieser Untersuchung wird motorisch wie Bild fuer Bild die kinematographische Registrierung der Art und Weise analysiert, in der Saeuglinge Wuerfel ergreifen, deren Seiten ein Zoll lang sind. Die Untersuchung fuehrt einige photographische Arbeitsmethoden vor, wodurch menschliche Taetigkeit (human behavior) analysiert und in zeitliche und raeumliche Formen (patterns) zerlegt werden kann. Als Versuchspersonen dienten je zwoelf oder mehr Saeuglinge in jedem der folgenden Alter: 16, 20, 24, 28, 32, 36, 40 und 52 Wochen.

Das Fassen hat vier Stufen: (1) Man fasst einen Gegenstand ins Auge, (2) Man langt danach, (3) Man erfasst ihn, (4) Man behandelt ihn. Betrachtet man es von oben herab, so zeigen sich drei Formen des Langens (reaching). Sie erscheinen bei Saeuglingen der obenerwaehnten Alters in folgender Reihenfolge: (1) dei rasche ·Fegbewegung mit dem Handruecken (backhand sweep); (2) die weitschweifige Annaeherung (circuitous approach) einschliessend (*a*) die seitliche Fegbewegung mit dem Handruecken, der eine Bewegung in der entgegengesetzten Richtung folgt; (*b*) die sehr weitsch weifige zusammenscharrenden (scooping) Annaeherung, (*c*) die nur etwas weitschweifige Annaeherung; und (3) die direkte Annaeherung. Beschauung von der Seite erweist, dass sehr junge Saeuglinge, wenn sie nach Gegenstaenden langen, entweder die Hand ueber den Tisch hingleiten lassen, oder die Hand so heben und senken, dass sie einen Bogen beschreibt. Aeltere Saeuglinge lassen die Hand dem Wuerfel entgegen gleiten (plane). Es gibt vier Stufen der Anpassung bei dem Langen: (1) das anfaengliche Vorruecken (initial advance), (2) das beschleunigte Vorruecken, wobei die Hand die Schnelligkeit ihrer Vorwaertsbewegung beschleunigt, obwohl das Ziel (die Bestimmung) (destination) der Hand sich noch nicht ermitteln laesst, (3) die Stufe des Geraderichtens (alignment) wobei sich die Hand so richtet, dass ihr endliches Ziel nun nun nicht mehr fraglich ist, und (4) *die kulminierende Stufe, in der sich die Hand zum Fassen richtet* (sets itself for the grasp). Die Art, wie das Kind beim Langen den Daumen haelt, deutet ungefaehr an, wie es den Wuerfel erfassen wird. Zeigt der Daumen nach innen, so wird das Kind den Wuerfel so erfassen, dass der Daumen den Fingern gegenueber steht. Haengt der Daumen herunter oder kruemmt er sich unter die innere Handflaeche, so wird der Saeugling den Wuerfel ohne Entgegensetzung des Daumens erfassen. Die Entwicklung des Langens und des Erfassens gibt ausgezeichelte Beispiele fuer das Fortschreiten des Reifens von den groeberen zu den feieren Muskeln. Die fruehe Annaeherungsweise offenbart eine ungeschliffen funktionierende Hand am Ende eines schlecht gelenkten Armes, waehrend die spaetere Annaerherungsweise einen gut koordinierten Arm unter dem leitenden Einfluss eines ziemlich gut entwickelten Grifforgans (prehensile organ) offenbart. Beim Langen findet man zuerst ein krallenartiges Schliessen, wobei der Daumen fast bewegungslos ist und keiner der Finger vorherrscht, und danach eine nippende, pressende Art des Schliessens, deren Hauptbestandteile der Daumen und Zeigefinder sind. Es gibt zehn Arten des Fassens, die sich in einer genetischen Reihenfolge anordnen lassen: (1) Keine Beruehrung, (2) Beruehrung, (3) primitives Quetschen (squeeze), (4) Quetschendes Ergreifen (squeeze grasp), (5) Ergreifen mit der Hand (hand grasp), (6) Ergreifen mit der inneren Handflaeche, (7) das hoeherstehende Ergreifen mit der inneren, (8) das tieferstehende Ergreifen mit dem Zeigefinger, (9) das mittlere Ergreifen mit dem Zeigefinger und (10) das hoeherstehende Ergreifen mit dem Zeigefinger.

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THE LIMITS OF LEARNING ABILITY IN KITTENS*

From the Animal Laboratory of the Department of Psychology, Columbia University

By

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CONTENTS

I

INTRODUCTION

The position of the cat in the field of animal intelligence is not nearly so well defined as is that of the white rat or the monkey. Certain investigators have confirmed the popular opinion that cats are rather stupid animals. Others have maintained that if cats be given problems suitable to their motor equipment they will solve them readily and prove themselves to be as intelligent as many of the "higher" animals. On the one hand, Thorndike (23) holds that cats are able to master problems only by a slow trial-and-error process, are unable to profit by being put through an act, and incapable of intelligent imitation and reasoning. He found the cat, as did Hamilton (9), to be generally less intelligent than the dog and considerably below the monkeys in the manner and speed of problem-solving. Shepherd (18), and likewise Drescher and Trendelenburg (7), also regard cats as incapable of making use of tools and therefore inferior to monkeys and the higher apes.

Hobhouse (11), on the other hand, discovered no essential difference in the learning capacities of the dog, elephant, cat, and the otter. Yarbrough (26) found, in the the learning stage of a delayed response, that his cats were far superior to Hunter's dogs and equal to the best of Hunter's raccoons. While he did not obtain as long delays as those previously secured on raccoons and dogs, Yarbrough did not attempt to reach the limits of the cat's ability in this respect. The long

delays obtained by Cowan (5) seem to indicate that her cat was equal to raccoons in this type of problem. The remarkable delays successfully spanned by Adams' (1) cats would place them in a class with the larger apes. Certain psychologists, namely, Hobhouse (11), Berry (2), Teyrovsky (20), and Adams (1), have found, in opposition to Thorndike (23), that cats are capable of imitation, and they believe that Thorndike's explanation of trial-and-error learning is inadequate. Hobhouse and Teyrovsky concluded that cats learn by perceiving relations and making use of practical ideas. Adams thought that the behavior of his cats, in several cases at least, showed the presence of practical or even of articulate ideas.

Evidence bearing on the intelligence of cats from which the above conclusions were obtained comes mainly from four sources: (*a*) problems in which the subject was tested in some sort of problem situation with no outside help, (*b*) problems in imitation, (*c*) problems in which the cat was put through the required act, and (*d*) problems of the delayed-response type. A summary of the studies dealing with these several types of problems are presented in Tables 1, 2, 3, and 4. It is not unlikely that the differences of opinion noted above are due in part to the type of activity tested and to other essential differences in the experimental conditions. A brief analysis of this material will be offered with the aim of bringing out diversities of this sort.

In the majority of learning tests with no outside help, the animals have been required to operate various devices, such as pulling a string, pushing a bar, rolling a

ball, upsetting a tumbler, pressing a lever, or going to a particular box or door. In few cases were these tests made with standardized problem boxes adapted to the presentation of tasks of varying difficulty by means of which the limits of learning might be found. The number of subjects used in the various experiments was usually so small that only a description of the behavior of individuals rather than of group averages could be reported. As will be seen from Table 1, the average number of animals used in any single test was 4, with a range of from 1 to 12 animals. The cats used by various experimenters ranged in age from 8 weeks to 6 years. They also differed markedly in the amount and type of their previous laboratory training. Some animals were given no preliminary training in problem-solving while others had been trained previously on from 1 to 10 other problems.

The incentives used varied with the experimenter, and sometimes they were not kept uniform within the same set of tests. Food such as fish, beef, or liver, served as the reward in many of the problems. In some cases the kind of incentive was not mentioned, and in others it varied with different animals in the same test. The length of the interval between feeding and running was not even approximately the same in the various experiments. Thorndike states merely that his animals were hungry. Adams starved his cats 14 hours or more, while Teyrovsky used either 8 or 12 hours of starvation. Hobhouse noted that his cat obtained food for itself in between the experiments; Hamilton always fed the subjects a bit of food just before the experiments so that their hunger would be "partially appeased."

TABLE 1

SUMMARY OF PREVIOUS WORK: PROBLEM METHOD

Experimenter	Problem	No.	Subjects Sex	Age	Problems previously attacked	Incentive
Thorndike (23) (1898)	A. Pulling wire loop	8	Not given	3-19 mo.	CI, or none	Fish or meat
	B. Pulling wire loop or string	1	Not given	8-10 mo.	A	Fish or meat
	C. Turning button	11	Not given	3-19 mo.	A, AB, or none	Fish or meat
	D or D. Pulling string	7	Not given	4-19 mo.	C, AC, ABC, CFG, CIAH	Fish or meat
	E. Poking paw through bars and pulling string	4	Not given	3-11 mo.	C, CD, or AC	Fish or meat
	F. Poking paw through bars and pulling string in proper direction	5	Not given	5-8 mo., or not given	C, or not given	Fish or meat
	G. Pressing thumb latch	8	Not given	5-19 mo., or not given	CF, ACE, ACD, or not given	Fish or meat
	H. Pushing and getting out of door before it swings back	9	Not given	4-11 mo., or not given	CDDEZ, ACEG, CFGDZ, CEZ, CIA, or not given	Fish or meat
	I. Pressing bar	8	Not given	4-11 mo.	ABCDDZ, CDDEZHJ, C, CEZH, ACEGHJZ, or CFGDZHJ	Fish or meat
	J. Pulling loop, knocking down support, opening door	5	Not given	5-11 mo., or not given	CDDEZH, ACEGH, CFGDZH, or not given	Fish or meat
	K. Depressing platform, pulling string, pushing bar	5	Not given	5-11 mo., or not given	CDDEZHJI, ACEGHJZI, CFGDZHJI, or not given	Fish or meat
	L. performing acts in A, D, and I	3	Not given	6-8 mo.	CIAHD	Fish or meat
	Z. Licking or scratching	7	Not given	3-19 mo.	CDDE, ABCDD, ACEGHJ, CFGD, CE, ACE, or ACDG	Fish or meat
Hobhouse (11) (1901)	F. Pushing brass loop off iron lever	1	M	1 yr.	ABCDE	Meat in box
Berry (2) (1908)	B. Pulling string	4	2 M, 2 F	2 mo., and "adult"	A	Piece of beef
	C. Turning button and pulling loop	3	2 M, 1 F	2 mo.	AB	Beef
	D. Turning button on floor	1	M	2 mo.	ABC	Beef in hole below button
	E. Raising small trap door	2	1 M, 1 F	2 mo.	AB, or ABC	Meat
	G. Getting meat out of bottle	3	1 M, 2 F	2 mo., and "adult"	ABCEF, or ABCDF	Meat

TABLE 1 (*continued*)

Experimenter	Problem	No.	Subjects Sex	Age	Problems previously attacked	Incentive
Hamilton (9) (1911)	Finding the unlocked door out of 4, never the one previously unlocked	5	Not given	1 yr. 8, 10 wk.		Food
Shepherd (18) (1915)	A. Pulling in stick tied to end of string	2	Not given	"Fully grown"	None	Meat at end of stick
	B. Reaching for and drawing up lever	2	Not given	"Fully grown"	A	Meat on lever
Yarbrough (26) (1917)	A. Going to the lighted of 3 boxes	3	2 M, 1 F	"About 10 mo."	None mentioned	Raw steak
	B. Going to the 1 of 3 boxes from which sound comes	3	1 M, 2 F	2 yr. or more	None mentioned	Raw steak
Tevrovsky (20, 21) (1925)	D. Pulling rope attached to board	3	2 M, 1 F	Not given	C	*Meat on board*
Drescher and Trendelenburg (7) (1927)	A. Reaching for food outside cage only if it is within range	Not given	Not given	Not given	None mentioned	Piece of food
	B. Drawing in food by attached ring	"	Not given	Not given	Probably A	Food
	C. Drawing in food with rake	"	Not given	Not given	Probably A and B	Food
	D. Turning potter's wheel through 180°	"	Not given	Not given	Probably A, B, and C	Food on wheel
	E. Pulling in food by string or stick	"	Not given	Not given	Probably A, B, C, and D	Food
	F. Removing obstacle boxes	"	Not given	Not given	Probably A, B, C, D, and E	Food
	G. Climbing wire partition	"	Not given	Not given	Probably A, B, C, D, E, and F	Food
	H. *Going in roundabout ways to goal*	"	Not given	Not given	Probably A, B, C, D, E, F, and G	Food
Adams (1) (1929)	A. Thorndike's A (above)	12	5 M, 7 F	4½-48 mo.	F, DEF, or none	Regular diet or salmon or liver
	B. Thorndike's B (above)	6	2 M, 4 F	4½-7 mo.	A	Regular diet
	C. Thorndike's C (above)	6	2 M, 4 F	5½-9½ mo.	A and B	Regular diet, liver, catnip, salmon
	D. Pulling or pushing lever	9	4 M, 5 F	7-27 mo.	E, F, H, or none	Liver on bar
	E. Going round various obstructions	2	1 M, 1 F	6 mo.	None	Liver in cage
	F. Pulling vertical or horizontal string	13	6 M, 7 F	4-28 mo.	G, D, DE, DG, or none	Liver at end of string
	G. Pulling box under suspended lure	3	2 M, 1 F	11-19 mo.	DF, DFH, DEF; all given preliminary practice in pulling boxes	Liver at end of string

TABLE 1 (*continued*)

Experimenter	Problem	Distribution of practice	Norm of mastery	Manner of scoring failures	Results
Thorndike (23) (1898)	A	1-15 tr. in suc.; 1-3-da. int.	5-18 tr. in 20 sec.	Usually a trial was considered failed and cat was removed if problem was not solved in 10-15 min. Some, however, were left in boxes 6-20 min.; 2 stayed in "for hours." In certain cases the cat was considered to have completely failed after 4 suc. failures. In other cases "they never succeeded again though given numerous opportunities."	All learned in 18-34 tr.
	B	Not given	Not given		Learned. Tr. not given.
	C	2-25 tr. in suc.; 1-hr., 1-3-da. int.	2-30 tr. in 20 sec.		All learned in 8-83 tr.
	D or D	1-32 tr. daily	2-30 tr. in 20 sec.		All learned in 3-43 tr.
	E	3-8 tr. daily	1-5 tr. in 20 sec.		All learned in 7-12 tr.
	F	Not given	Not given		4 failed, 1 learned in 15 tr.
	G	Not given in most cases	12 tr. in 20 sec.; not always given		5 failed; 2 learned in 91 and 106 tr.
	H	1-6 tr. in suc.; 1-3-da. int; some not given	2-17 tr. in 20 sec.		2 failed; 7 learned in 7-23 tr.
	I	3-23 tr. in suc.; 1-2-da. int.	11-36 tr. in 20 sec.		All learned in 14-44 tr.
	J	3-26 tr. in suc.; 1-4-da. int.	7-11 tr. in 20 sec.		2 failed; 3 learned in 48-102 tr.
	K	3-23 tr. in suc.; 1-2-da. int.; not always given	2-12 tr. within 70 sec.		2 failed; 3 learned in 66-128 tr.
	L	3-21 tr. in suc.; 1-2-da. int.	4-12 tr. in 49 sec.		All learned in 83-109 tr.
	Z	3-33 tr. in suc.; 1-3-da. int.	2-33 tr. in 20 sec.		All learned in 42-103 tr.
Hobhouse (11) (1901)	F	3-9 tr. daily	Not given	Not given; mentioned once that cat "refused to try."	Succeeded more or less awkwardly in 12 of 13 tr.
Berry (2) (1908)	B	1-9 tr. daily	Not given	Not given	All learned *either alone or together*; tr. not given
	C	Not given	Not given	Not given	Same as in B
	D	1 tr. or more daily	1 tr. in 5 min.	Not given	Learned in 1st tr.
	E	Probably all in 1 da.	1 successful tr.	Not given	Learned in 1st tr.
	G	Same as in E	1 successful tr.	Allowed 20 min. per tr.	2 learned in 1st tr.; 1 learned in 3rd tr.

TABLE 1 (*continued*)

Experimenter	Problem	Distribution of practice	Norm of mastery	Manner of scoring failures	Results
Hamilton (9) (1911)		10 tr. daily for 10 da.	Not required	If they lie down or sleep they are "urged to return to me for a bit of extra tempting food."	In 40% of tr. of cats and 70% of kittens there were repeated efforts to open same door without trying others first. Poorest type.
Shepherd (18) (1915)	A	Not given	Not required	Complete failure after 6 tr. of 2 min. each	Both failed. Some "scrambling" near the meat.
	B	Not given	Not required	Same as in A	Both failed.
Yarbrough (26) (1917)	A	10 tr. daily	90-100% correct	No failures recorded	Learned in 110-170 tr.
	B	10 tr. daily	64-86% correct	No failures recorded	Learned in 70-180 tr.
Teyrovsky (20, 21) (1925)	D	5 tr. in suc.; twice daily	Not given in summary	Not given in summary	All learned
Drescher and Trendelenburg (7) (1927)	A	Not given	Not given	Not given	Reached for food when it was 7 cm. or more beyond range
	B	Not given	Not given	Not given	Failed
	C	Not given	Not given	Not given	Failed
	D	Not given	Not given	Not given	Failed
	E	Not given	Not given	Not given	Failed
	F	Not given	Not given	Not given	Failed
	G	Not given	Not given	Not given	Failed if 2 m.; learned 1 m.
	H	Not given	Not given	Not given	Partially learned
Adams (1) (1929)	A	1-11 tr. in suc.; 1½-hr.-3-da. int.	4-20 perfect tr. in suc.	Complete failure after 5 suc. tr. of 30 min. each.	8 failed; 5 learned in tr. 1, 5, 11, and 13
	B	Not usually given	5-20 perfect tr. in suc.	Same as in A	3 failed; 5 learned in 3-11 tr.
	C	2-8 tr. in suc.; 1-hr.-2-da. int.	7 perfect tr. in suc.	Complete failure after 5 or 9 suc. failures of 20-60 min.	5 failed; 1 learned in tr. 3.
	D	1-6 tr. in suc.; 1-hr., 1-da., 1-wk. int.	Not given	Complete failure after 2 suc. failures of 10 min. ea.	3 learned 1st problem, 2 of these the 2nd, and 1 the 3rd.
	E	Not given	Not given	Not required	Goes to right regardless of position of obstruction
	F	20-min.-9-da. int. No tr. at time not usually given	8-15 suc. perfect tr. or not given	Complete failure after 1-2 tr. of 5-10 min. each	About half learned in 2-3 tr.; others failed
	G	1-5 tr. in suc.; 1-hr.-1-wk. int.	Not given	Complete failure after 1-3 suc. failures of 4-20 min.	1 cat succeeded in moving box, getting reward in 2 out of 5 tr.

TABLE 2

SUMMARY OF PREVIOUS WORK: IMITATION

Experimenter	Problem	No.	Imitators Sex	Imitators Age	Imitatees	Problems previously attacked: Imitators	Problems previously attacked: Imitatees	Incentive
Thorndike (23) (1898)	D. Pulling string	4	Not given	3-11 mo.	1 cat	EZ, EZHI, or ACEGHIJK	D at least	Fish
	A. Pulling wire loop	1	Not given	3-5 mo.	1 cat	Not given	A at least	Fish
	B. Pulling wire loop or string	1	Not given	5-7 mo.	1 cat	Probably EZHI	B at least	Fish
	X. Climbing wire cage	1	Not given	Not given	2 cats	Not given	X at least	Fish
	Y. Climbing wire cage in response to a sound	2	Not given	4-8 mo.	2 cats	Used to climbing cage as *E* approached	Y at least	Fish
Hobhouse (11) (1901)	A. Pulling dangling string	1	M	1 yr.	*E* or dog	None	A	Meat or fish at end of string
	B. Pressing pole projecting outside cage	1	M	1 yr.	*E*	A		Meat in box
	C. Pulling out bolt from outside of box	1	M	1 yr.	*E*	A and B		Meat in box
	D. Pushing back bolt	1	M	1 yr.	*E*	ABC		Probably meat in box
	E. Lifting and pulling catch	1	M	1 yr.	*E*	ABCD		Probably meat in box
	G. Pulling spike out of chain and opening box	1	M	1 yr.	*E*	ABCDEF		Probably meat in box
	H. Upsetting tumbler, tripod, or candlestick	1	M	1 yr.	*E*	ABCDEFG		Milk, meat, or fish
	I. Lifting teapot lid	1	M	1 yr.	*E*	ABCDEFGH		Fish in teapot
	J. Clawing loops of drawer	3	M	1, 2, 4 yr.	*E*	AH or ABCDEFGHI		Meat in drawer
	K. Sliding lid of toy box	2	M	1, 2 yr.	*E*	AHJ or ABCDEFGHIJ		Meat in box

TABLE 2 (*continued*)

Experimenter	Problem	No.	Imitators Sex	Age	Imitatees	Problems previously attacked: Imitators	Problems previously attacked: Imitatees	Incentive
Berry (2) (1908)	A. Jumping from box to table	3	2 M, 1 F	2 mo.	Manx mother	None	None	Meat on table
	C. Turning button and pulling loop	1	F	"adult"	3 kittens	AB	AB	Beef
	D. Turning button on floor	1	F	"adult"	1 kitten	ABC	ABCD	Meat below button
	E. *Raising small trap door*	1	M	2 mo.	2 kittens	ABC	ABCE or ABCDE	Meat under door
	F. Rolling tennis ball into hole	4	2 M, 2 F	2 mo., "adult"	*E* or kittens	ABCD, ABCE, or ABCDE	ABCEF or ABCDEF	Meat under trap door
	G. Getting meat out of bottle	1	M	2 mo.	1 kitten	ABCDEF	ABCDEFG	Meat
	H. Getting down from top of cage	2	1 M, 1 F	2 mo.	1 kitten	ABCEFG	ABCDEFG	Meat on floor
Tepovsky (20, 21) (1925)	A. Taking indirect route to reward and avoiding obstructed direct route	3	2 M, 1 F	2½ mo.	3 kittens	None	Not even *A*	Meat and milk behind one end of screen
	B. Same as in A	1	F	2½ mo.	1 kitten	None	Not even B	Same as in A
	C. Overturning box by means of projecting stick	7	5 M, 2 F	4-5 mo., unknown	*E* and cats	Possibly A or B	C	Food under box
	E. Loosing ring and pulling rope	4	3 M, 1 F	Not given	*E*	CD or C		Meat
Drescher and Trendelenburg (7) (1927)	F. Opening *lid of box*	1	Not given	Not given	*E*	Not given		Piece of food
Adams (1) (1929)	B. *Thorndike's* B (above)	1	F	6 mo.	1 cat	Failed in *A*	AB	Regular diet
	C. Thorndike's C (above)	1	F	8 mo.	1 cat	AB	ABC	Regular diet, salmon liver, catnip
	D. Thorndike's D (above)	2	1 M, 1 F	9 mo.	*E* or cat	E or EG	D	Liver

TABLE 2 (*continued*)

Experimenter	Problem	Distribution of practice	Norm of mastery	Manner of scoring failures	Method	Results
Thorndike (23) (1898)	D	1-3 tr. in suc. after 5-35 of imitatee; 2-72-hr. int.	Imitator must perform act more quickly than it would have done alone. The time factor should be fairly constant. Times should decrease the more cat sees the act done.	5-15 min. per tr.; complete failure after 7 suc. failures	Imitator in adjoining cage Imitatee performed act 90-221 times	2 failed; 1 partially succeeded; 1 learned in 6 tr.
	A	Not given		5-10 min. per tr.	Put with imitatee after 45-75 sec.	Learned by accident
	B	Not given		5-10 min. per. tr.; total no. of failures not given	Imitator saw imitatee perform act 3-26 times	Failed
	X	Not given		Not given	Imitator with imitatees; imitatees climbed 60 times	Failed to climb
	Y	Not given		Not given	Imitatee climbed 5-10 sec. after signal given	Not learn quicker than they would have alone
Hobhouse (11) (1901)	A	7-14 tr. in suc.; 1-14-da. int.	5 suc. times "without hesitation."	Not given	*E* or dog pulled string before cat in first 29 tr.	Succeeded in 35 tr. including those shown
	B	Not given	Not given	Complete failure after 3 suc. ones	Not given	Failed
	C	3-9 tr. in suc.; 1-2-da. int.	2 suc. perfect tr.	Not given	*E* showed in tr. 1, 2, 10, 11; *E* helped in tr. 5 and 14	Succeeded in 15 tr. including those shown
	D	Not given	Not given	Not given	Not given	"Altogether failed"
	E	Not given	Not given	Not given	Not given	Only partially successful
	G	Not given	Not given	Complete failure after 3 suc. ones	*E* showed cat in 2 tr.	Failed
	H	5-12 tr. daily	1-7 perfect tr.	Not given	*E* showed cat in tr. 1-6	Learned in tr. 29
	I	9 or fewer in suc.; 1-da. int.	3 repetitions without failure	Not given	*E* removed lid 5 times allowing cat to claw out food	Succeeded in tr. 6-11
	J	Not given	Not given	Not given	*E* showed cats 2 or more times	1 failed; 1 learned; tr. not given
	K	Not given	Not given	Not given	*E* showed or helped in first 3-5 tr.	Failed

TABLE 2 (*continued*)

Experimenter	Problem	Distribution of practice	Norm of mastery	Manner of scoring failures	Method	Results
Berry (2) (1908)	A	All tr. same da.	One jump	Not given	Kittens and mother put together on box	Jumped after 1-7 observations
	C	Not given	Last 6 tr. performed in 1 min.	Not given	Imitator put with 1, then another kitten 42 times	Learned in 43 tr.
	D	1 or more tr. daily	Not given	5-10 min. per tr.	Imitator put in with imitatee 15 tr. but not allowed to get reward	Learned after 15 tr.
	E	1-25 daily	Last 5 tr. performed in 5-10 sec.	Complete failure after 5 suc. failures of 20-90 min. each	After 5 failures cat put in with imitatee 56 times	Learned in 58 tr.
	F	Several in suc.	2 or more perfect	Not given	After 1-14 failures cat shown 2-10 times in suc.	Learned in 1 wk., 70, 71, and 258 tr.
	G	1-2 daily	1 tr. in less than 2 min.	Complete failure after 4 suc. tr. of 6-40 min. ea.	After cat failed put in for 1 tr. with imitatee	Learned after 5 tr.
	H	All tr. same da.	1 jump	Not given	All put together on top	Jumped only after 2-3 observations
Teyrovsky (20, 21) (1925)	A	3 tr. in suc; 8-hr. int. for 5 da.	Probably 15 perfect tr.	Not given in summary	1 cat saw act performed 0 times, 1-3 times, 1-6 times, 1-9 times, during every period	First cat made direct route on tr. 5, 2nd on tr. 4, 3rd on tr. 2, 4th failed to learn it
	B	Same as in A	Same as in A	Not given in summary	Imitator given 3 tr. a period following 9 tr. of imitatee	Imitator failed Imitatee learned in 47 tr.
	C	5 tr. in suc.; 2 times daily	Not always given	Not given in summary	Cats put in singly or together, *E* showed act several times	All finally learned
	E	2-15 daily	4 suc. perfect tr.	Not given in summary	After certain length of time *E* performed act for cat	2 failed in 66, 143 tr. 2 learned in tr. 31, 33
Drescher and Trendelenburg (7) (1927)	I	Probably all in same day	Not given	Not given	*E* performed the act several times on the fourth tr.	Learned
Adams (1) (1929)	B	All in suc.	More than 4 perfect tr. in suc.	30 min. per tr.	Shown every other tr. after 5 failures	Learned after being shown 3 times
	C	2-3 tr. in suc.; 8-hr. int.	Not given	Complete failure after 5 failures of 3-55 min. per tr.	Same as in B	Failed but pawed button
	D	5 tr. 2 times daily	Not given		*E* showed cat 2-3 times after it failed 5-6 times; then again	1 failed; 1 learned after shown 2 times

The number of trials at a practice period ranged from 1 to 30, while the temporal interval between the periods was as short as 20 minutes or as long as 2 weeks. In certain experiments no norm of mastery was given, but when reported it varied from 1 to 20 successive perfect trials. In some instances failure on one trial was taken to mean lack of capacity to learn, whereas in other cases from 2 to 13 successive failures was supposed to indicate such lack of capacity. When a time norm was used, the time per trial allowed for success ranged from 2 to 30 minutes or even longer.

In the imitation tests (Table 2) some experimenters put the two animals together in the same cage while others separated the imitator and imitatee. The imitator was given training in the particular problem in certain experiments before it was tested for imitation. Sometimes the imitatee was a cat, sometimes a dog, and sometimes the experimenter himself. The imitatee performed the required act with the possibility of being observed by the imitator from 2 to 221 times in various cases. The norm of mastery ranged from requiring the imitator to perform the act precisely as done by the imitatee to requiring it merely to execute the act more quickly than it would have done without observation.

In testing for delayed response (Table 3) two main methods were used. In the one method a conditioning process to light, sound, or to the experimenter himself was first secured, after which delays of varying intervals were introduced. This method was used by Yarbrough and by Cowan. In the other, employed by Adams, the conditioning process was eliminated "by

using the act itself of loading the correct box as its indicator." This latter method seems to have worked out very satisfactorily and the method itself no doubt partially accounts for the higher indices obtained in this case.

The two experimenters who used the tuition method, i.e., putting the animals through the required act (Table 4), in the main used the same technique. Since this is true, and since the results obtained were negative in all tests, no discussion of these data would seem to be necessary.

In general, the present experiment may be thought of as a continuation of the line of tests summarized in Table 1. As we have suggested above, however, the experiments there listed may be criticized because of the small groups of animals used and the lack of standardization of apparatus and procedure. In the present experiment we have used groups of such size that statistical analysis becomes possible, a type of result which contrasts sharply with the mere descriptions of individual animals which characterize the work of previous investigators. Such analysis enables us to draw conclusions regarding cats in general *vs.* individual animals. We have also succeeded in standardizing the apparatus and procedure beyond any point heretofore attempted. For example, most investigators have secured increases in complication of the problem by multiplying devices of various sorts, involving divergent action systems. Under such conditions it is quite impossible to compare the relative complexity of the series of tests employed. We have

TABLE 3

SUMMARY OF PREVIOUS WORK: DELAYED RESPONSE

Experimenter	Problem	No.	Subjects Sex	Age	Problems previously attacked	Incentive
Yarbrough (26) (1917)	A. Going after delay to the 1 of 3 boxes that had been lighted	2	M, F	10½ mo.	Learned to go 90-99% of time to correct box in A without delays	Piece of raw steak
	B. Going after delay to the 1 of 3 boxes from which sound came	2	M, F	2 yr. 11	Learned to go 64-86% of time to correct box in B without delays	Steak
	C. Going after delay to the 1 of 2 boxes that had been lighted	1	M	11 mo.	Mastered 4 sec. delay in A	Steak
	D. Going after delay to the 1 of 2 boxes from which sound came	2	M, F	2 yr.	Mastered 4 sec. delay in B	Steak
Cowan (5) (1923)	Following *E* out of 1 of 2 doors after delay	1	F Manx	6 yr.	*45 trials on same problem without delays*	Piece of kidney
Adams (1) (1929)	H. Going after delay to the 1 of 4 boxes in which cat had seen meat placed	2	M, F	6, 20 mo.	F; *none*	Piece of liver

TABLE 3 (*continued*)

Experimenter	Problem	Distribution of practice	Norm of mastery	Method	Results
Yarbrough (26) (1917)	A	10 tr. daily	More than 73% of total trials correct	Lengthened delay from 0 to 2, 4, and 6 sec.	2- and 4-sec. delays learned in 130-200 tr. each; 6-sec. delay partially learned in 130 tr.
	B	10 tr. daily	More than 84% of total trials correct	Lengthened delay from 0 to 2, 4, 6, and 26 sec.	2- and 4-sec. delays learned in 60-170 tr. each; 6-sec. delay partially learned; tr. not given
	C	10 tr. daily	More than 84% of total trials correct	Lengthened delay from 2, 4, 6, 8, 10, 14, to 16 sec.	6-, 8-, 10-, 12-, and 16-sec. delays learned in 30-40 tr. each; 18-sec. delay learned in 100 tr.
	D	10 tr. daily	More than 76% of total trials correct	Lengthened delay from 2, 4, 6, 8, 10, 14, to 16 sec.	2-, 4-, 6-, 8-, 10-, and 14-sec. delays learned in 30-40 tr. each; 16-sec. delay learned in 90 tr.
Cowan (5) (1923)		10 tr. daily	More than 66% of total trials correct	Lengthened delay from 0 to 10, 20, 25, and 30 sec.	10-, 20-, 25-, and 30-sec. delays learned in 20, 72, 96, and 37 tr.
Adams (1) (1929)	H	1-7 tr. in suc.; 1-hr.-5-da. int.	No constant norm	Interspersed long and short delays for 98 tr. with 1 cat and 40 with other.	1-min.-3-hr. delays mastered 40-100% of time by 1; 16-hr. delay mastered 4 out of 6 times by it; 20-sec.-30-min. delays mastered by the other cat 20-87% of time

TABLE 4

SUMMARY OF PREVIOUS WORK: TUITION, "BEING PUT THROUGH ACT"

Experimenter	Problem	No.	Subjects Sex	Age	Problems previously attacked	Incentive
Thorndike (23) (1898)	F. Poking paw between bars and pulling string in right direction	1	Not given	8-10 mo.	Probably ABCDDZI	Piece of fish
	G. Pressing thumb latch	3	Not given	3-7 mo.	CDDEZHIJK, CEZHI, or AC	Fish
	KKK. Poking paw out at one side of door and pressing bar of wood	1	Not given	18-19 mo.	Probably ACDGZ	Fish
	C. Turning button	5	Not given	3-10 mo.	A, AB, or none	Not mentioned
	A. Pulling wire loop	1	Not given	8-10 mo.	Probably none	Probably fish
	B. Pulling wire loop or string	1	Not given	5-7 mo.	Probably CDDEZHIJK	Probably fish
Adams (1) (1929)	C. Thorndike's C (above)	1	M	9 mo.	AB	Regular diet

TABLE 4 (*continued*)

Experimenter	Problem	Distribution of practice	Norm of mastery	Manner of scoring failures	Results
Thorndike (23) (1898)	F	1 tr. alone following 10-15 tr. in which *E* puts cat through proper movements	Not given	10-20 min. allowed for tr.	Failed after being put through 77 times
	G	Same as in F	Not given	10-20 min. allowed for tr.	Failed after being put through 30-141 times
	KKK	Same as in F	Not given	10-20 min. allowed for tr.	Failed after being put through 65 times
	C	Not given	Cat to perform act in same way in which it was put through	1-2 min. allowed for tr.	All but 1 used a different method from one shown; time with instruction no shorter than without
	A	Not given	Same as in C	1-2 min. allowed for tr.	Same as in C
	B	Not given	Same as in C	1-2 min. allowed for tr.	Same as in C
Adams (1) (1929)	C	2-6 tr. in suc.; 1-da. and 8-hr. int.	Not given	Complete failure after 5 tr. of 5 or 30 min. each.	Failed after being shown 8 times and put through the act once

avoided this difficulty by making use of an apparatus in which regular increases in difficulty could be secured without making use of more than a single action system. The basic reaction employed, that of stepping on a plate in the floor of the cage, is one that can be utilized in the study of many other species and hence fulfils the conditions for comparative studies in this respect.

II

METHOD AND PROCEDURE

Apparatus. The apparatus used in the experiment was described by Jenkins (12), but has hitherto been unused in animal experimentation. The significant parts of the apparatus are as follows. The test cage consisted of a round, smooth, whitepine wood floor, free from knots, 135 centimeters in diameter, and painted battle-ship gray. It was completely surrounded by sides of ½-inch wire mesh, 45 centimeters high, and covered with a flat roofing of the mesh. The test cage thus formed (Figure 1) was shut off from a round inner area, the incentive compartment (F in the figure) by similar screening that likewise extended from the floor to the top of the box. Both the test cage and the incentive compartment had doors 15 centimeters in width and height. On the floor of the test cage were three plates, 1, 2, 3, spaced as shown in Figure 1. These plates were raised 1 centimeter above the floor, and were of the same material and color as the floor. The diameter of the incentive compartment was 45 centimeters, 1/3 that of the test cage, and of the same height. The diameter of the plates was 15 centimeters, 1/3 the diameter of the incentive compartment, and 1/3 the distance from the outer siding to the inner.

The following mechanism of control was used. The outer door, *o*, which served as entrance to the problem situation, was opened and closed manually by the experimenter. The inner door, *i*, was held shut or was allowed to slide back automatically by the operation of

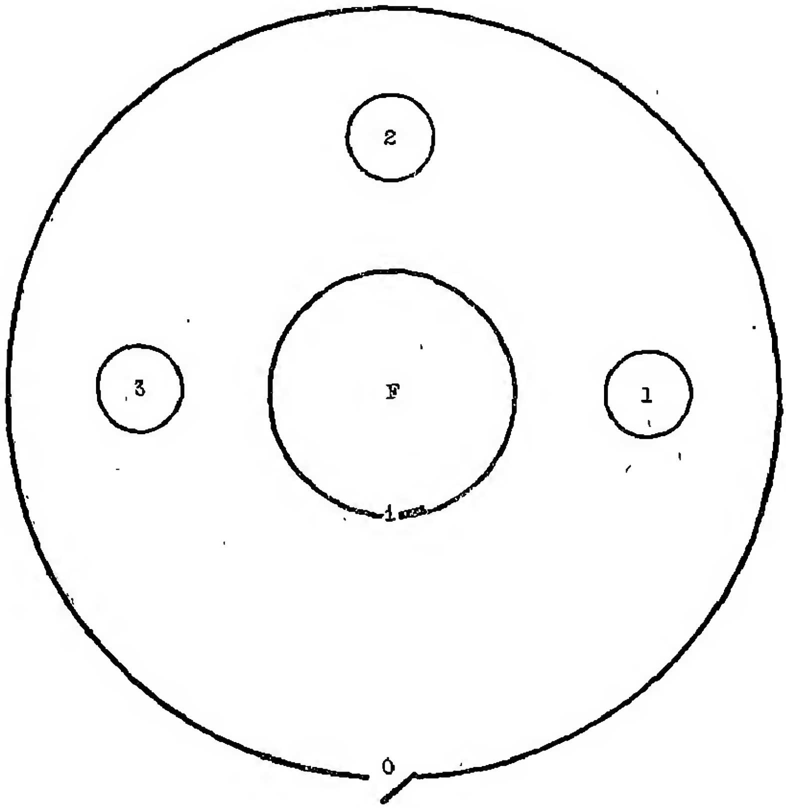

FIGURE 1
DIAGRAM OF THE FLOOR PLAN

an electro-magnetic device. The opening of this door gave the animal in the outer part free access to the incentive which the inner cage contained. Before the inner door was noiselessly released the cat had to react by touching one or more of the release plates as determined by the experimenter. The apparatus could be so adjusted at the switchboard, located about 5 feet

from the problem box, that the simple act of stepping on any one of the three plates would result in the opening of the inner door. By means of three relays it could be so adjusted that only a complicated pattern of reactions would bring about the desired result.[1] For example, the animal might be required to react to the plates in the order 3-2-1, or in the order 1-2-3. The experimenter merely had to set the apparatus so that only the appropriate acts would result in the opening of the door. The cat might be required to touch all of the plates twice in this order, 1-2-3, 1-2-3, or in the order, 3-2-1-2-3-1, or 1-3-1-2-3. Theoretically, the range of complication permitted by the apparatus was almost unlimited. Practically, the use of the apparatus was limited by the ability of the animal and by the patience of the experimenter.

The reaction plates were strung with fine copper wires so that electric shock could be used if desired. The mechanism used in controlling the electrical stimulation supplied to the plates was the same as that used in the Columbia obstruction apparatus of this laboratory (13). The problem box stood 45 centimeters above the floor. Daylight was excluded from the room in which the apparatus was located, the sole illumination of the box being a metal shaded 100-watt Mazda bulb that hung 9 centimeters above the center of the box. The experimenter sat at the switchboard, which was lighted by a 1-watt signal lamp. The experimenter was excluded from the view of the subject by a one-way light screen completely surrounding the box.

[1]For a complete description of the mechanism of control see (12).

TABLE 5
ANIMALS USED IN PRELIMINARY TESTS

Animal	Sex	Siblings	General description	Age in weeks at beginning of problem 1	2	3	4
A	M	D, J	black-white			8	
B	M	I	black			9	
C	M	E	maltese				8
D	M	A, J	brown tabby				8
E	M	C	maltese				8
F	M	G	orange				9
G	F	F	brown-orange				9
H	F	K	gray				9
I	F	B	black				9
J	F	A, D	black-white				8
K	F	H	brown tabby				9
L	M		brown		9		
M	M	N, S	black-white		9		
N	M	M, S	black		9		
O	F		gray-white		9		
P	F	R, T	black-white		9		
Q	F		brown tabby		9		
R	F	P, T	black-white		9		
S	F	M, N	black-white		9		
T	F	P, R	black-white	9			
Av.					9	8.5	8.6
Range						8-9	8-9

Subjects. The subjects of the experiment included 82 cats, 45 males and 37 females, secured from a local pet store. All of them were common short-haired cats of various colors and markings, as indicated in the brief description of them in Tables 5 and 6. With the exception of two litters that were born on boats coming from Texas and Argentina, all the animals were born and reared in New York or vicinity. In the beginning of the training series all cats were between 8 and 9 weeks of age. Since some of them were carried through more problems than others, and since some learned more quickly than others, their ages at the end of the training period differed by weeks or months.

Throughout the experiment, which extended from January, 1929, to May, 1930, there were from 12 to 30 kittens constantly housed in the laboratory. They

TABLE 6

ANIMALS USED IN VARIOUS EXPERIMENTS

No.	Siblings	Males General description	Age in weeks at beginning of step: I	II	III
1	33, 76	brown-white	8	9	10
2	26, 30, 3	brown tabby	8	9	10
3	2, 26, 30	black-white	8	10	11
4	10, 55	black-white	9	10	10
5	59	brown-white	9	10	10
6	6, 20, 51	black-white	9	10	10
7	52, 53, 54	black-white	8	9	10
8	17, 27	black-white	8	9	10
9	34	black	8	10	11
10	4, 55	brown-white tabby	9	10	10
11		gray-blue	9	10	11
12		black-white	9	10	11
13		brown-tabby	9	11	11
14	31, 69	black-white	9	10	11
15		brown-tabby	9	10	10
16	18, 84	brown-tabby	9	10	11
17	8, 27	black-white	8	9	10
18	16, 84	brown-tabby	9	10	11
19	61	gray-white	9	11	11
20	6, 51	white	9	10	11
21	64	brown tabby	9	10	10
22	24, 75	brown tabby	9	10	10
23	35	white	9	10	11
24	22, 75	black	9	10	10
25	73	brown tabby	9	10	
26	2, 3, 30	brown tabby	8		
27	8, 17, 27	black	9		
28	29, 71	black	9	10	10
29	28, 71	black	9		
30	2, 3, 36	brown tabby	8	10	11
31	14, 69	black	9		
32		orange	9	10	
33	1, 76	brown tabby	8	10	11
34	9	orange-white	9	10	11
35	23	white	9	11	
36		brown-white tabby	9	10	10
Av.			8.7	9.9	10.5
Range			8-9	9-11	10-11

TABLE 6 (*continued*)

No.	Siblings	Females General description	Age in weeks at beginning of step: I	II	III
51	6, 20	black-white	9	10	10
52	7, 53, 54	black-white	8	9	10
53	7, 52, 54	black-white	8	9	10
54	7, 52, 53	gray	8	9	10
55	4, 10	brown tabby	9	10	11
56		gray	9	11	12
57		brown tabby-white	9	10	10
58	67	red-brown	9	10	11
59	5	gray-white	9	10	11
60		gray tabby	9	10	10
61	19	gray-white	9	10	10
62		orange	9	10	11
63		black-orange	9	10	10
64	21	brown-white tabby	9	10	10
65		orange-black-white	9	10	11
66	74	black	9	10	11
67	58	brown tabby	9	10	11
68		black-white	9	10	10
69	14, 31	black	9	10	11
70	43	brown tabby	9	10	11
71	28, 29	brown tabby	9	10	10
72		black	9		
73	25	brown-white tabby	9		
74	66	black	9		
75	22, 24	brown tabby	9	10	10
76	1, 33	black-white	9	10	10
Av.			8.9	9.9	10.4
Range			8-9	9-11	10-12

lived in four heavy wire cages, each of which was 3 x 6 x 3 feet in size, in a large northeast room, near the experimental chamber on the tenth floor of a university building. In the cages were shelves, boxes, pans, cups of water, but no food during the period between tests. All kittens had access to food twice daily for about an hour at a time following experimentation. During these periods they were allowed the freedom of the room, both inside and outside the living cages.

The morning meal consisted of some one or more of the following: cooked cereal and milk, thick soups, custard, bread and milk, raw eggs, creamed salmon, and rice. The evening meal was mainly one of cooked or raw meat mixed with cereal and fresh vegetables. The following combinations of food were often given them: beef stew; liver, boiled and ground, with rice and chopped raw spinach; gizzards cooked with macaroni and chopped lettuce; whole raw beef heart; cooked chopped beef with cream of wheat and celery; cooked beef, bread, and spinach or tomato; and occasionally, fresh boiled fish or canned sardines, lettuce, and bread. Small doses of codliver oil were administered once or twice weekly because of its vitamine content. Garlic, cooked with the food, and lime water were given twice a week to prevent worms. To kill these parasites doses of vermifuge (M. and R. brand) were given every three or four weeks. The experimenter had to watch constantly for signs of stomach or intestinal parasites which are a menace to all young animals, especially the carnivores. Several kittens suffered from various stomach disorders from time to time which were probably due in part to the presence of parasites. The majority of the kittens, however, were in excellent condition throughout the experimentation, as judged by their activity and playfulness, their weight, general appearance, the eagerness with which they attacked their food, and the type of stools.

Distribution of Practice. All kittens were brought into the laboratory at least one week before their training periods were begun. This was done to adapt them

to the laboratory conditions. At the end of this time five preliminary trials initiated every cat into the problem box. One preliminary trial was given every morning and one every evening for 2½ days. During these trials, each of which lasted for 5 minutes, the inner door was left open, allowing the kitten free access to the food within. The unusual condition of being put alone into a strange room and in a strange situation was somewhat offset by the presence of food.

After the preliminary series was completed the training series was begun with a single trial. Trials 2 and 3 were given in the next running period, trials 4, 5, and 6 in the next, and trials 7, 8, 9, and 10 in the next. After these first 10 trials were finished, 10 trials a day, Sundays included, 5 in the morning and 5 in the evening, were given to each kitten. The 5 trials were given in immediate succession. Each animal was tested at approximately 12-hour intervals and had been without food during the preceding 9-12 hours. The hours of experimentation were from 11:00 to 2:00 during the first 8 months, and 10:00 to 1:00 throughout the last 8 months. The kittens were rotated in the order run so that no animal would be crowded out of its eating period. Thus an animal would be taken first at one period, second in the next, third in the next, etc. No kitten was allowed to eat food or have the freedom of the room until after it had been tested. When all cats were run and after the last had had access to food for from 10 to 30 minutes they were put back into their cages, from which the food was removed.

Incentives. Fresh chopped beef and canned or fresh

milk were used as rewards in the problem box. Success in any trial was rewarded by a bit of the beef or a lap or two of the milk. Early observations of the animals in their living quarters indicated that the cats' drive for raw beef was greater than for almost any other food, and that they did not easily tire of it. In fact, it was repeatedly observed that the kittens, even after they had eaten a quantity of the rations put out for them and were active in various parts of the room, would run to the experimenter if she entered with some raw beef, A few bits of the remaining beef were often brought in at the end of the experiment to lure the animals to one place and thereby catch them quickly. They would jump around climb up the experimenter's clothes and paw at the bits of beef in a very active manner. Although milk was selected but rarely in the problem box it was always present as a possible reward. Occasionally a kitten, especially a very young one, consistently refused beef and other meat whenever it was offered to it. Three or four of the 82 animals usually lapped the milk and refused the beef. All the others either disregarded the milk or only snatched a lap of it after having eaten the beef before the experimenter could remove it from the inner cage. That the motivation was strong was further indicated by the fact that as soon as the experimenter entered the living quarters preparatory to beginning the experiment the cats began to mew loudly and to climb the sides of the cages. They would fall over one another in attempting to get out when she opened the cage door to remove one for testing.

Norm of Mastery. Before any animal was considered to have mastered a problem it was required to solve it perfectly on 9 trials out of 10. In general, a perfect trial was one in which a kitten performed its act or acts directly upon being placed in the outer cage. A trial was not considered perfect if the animal went around the box one or more times before making the correct responses, if it touched or approached the wrong plate, or if it touched any plate more than once before reacting to another. The criteria of a perfect performance will be discussed in connection with each problem presented. No cat was allowed more than 5 minutes on any trial. If it failed to perform the task within that time it was removed from the top of the box, directly above where it was at the end of the 5 minutes, and was replaced in the box at the outer door for the following trial. The kittens were removed at 5-minute intervals to prevent their acquiring the habit of sleeping in the problem box. From a few preliminary trials given to 3 or 4 subjects, we found that if an animal was left in the problem box for longer periods of time it usually spent the most of the time in washing, sleeping, or sitting. If the kitten failed on the last trial of the series of five it was put back into its living cage and was not allowed access to other parts of the room or to food for 30 minutes. This involved a certain punishment in the postponement of the usual freedom and access to the regular meal.

The question arose as to what should be considered the point of final failure on any problem. We finally decided on two criteria of failure. Some kittens failed

consistently to secure the reward and would get so they would do nothing but sit in the problem box. We noted that no animal finally mastered a problem if it had failed in more than 50 successive trials. We continued some kittens through 200 trials all of which were failures. A limit of 100 successive failures was set, therefore, as being sufficient to indicate complete failure.

The majority of kittens were active from trial to trial and did not fail to get the reward in any consistent manner. Since no kitten that had not passed the norm of mastery by the 1000th trial ever learned it in the next 200 given it, 1200 trials were thought to be sufficient in the majority of cases. Although four or five kittens were given 1500 trials and still did not learn the problem, 1200 was usually considered to be the failing point.

III

PRELIMINARY TESTS

Before we tested our main groups it was necessary to ascertain in what order the several tasks should be given. Since no animals had been previously tried in this problem box we did not know whether it would be advantageous to begin with the simplest of situations and make the problems progressively difficult, or whether we should begin with a somewhat complex problem at the outset. In the preliminary investigation to settle this point, we set up four possible situations, any one of which might be used as a first task to be mastered. They were as follows: (*a*) requiring the animal to step on all 3 plates, but in no particular order, (*b*) requiring the animal to step on any 2 of the plates, in any possible order, (*c*) requiring the animal to step on Plate 2 only, and (*d*) requiring it to step on first any one plate, then any 2, and, finally, all 3 plates. Twenty kittens of the total 82 were used in the preliminary tests, as shown in Table 5. These several tests will be discussed in order.

Task 1. One kitten only was put on the first preliminary problem. This kitten, one of the liveliest in the group, failed to learn the problem within a reasonable time. In fact, she succeeded in setting off all 3 plates in the first trial only, although tested on 100 trials thereafter. In trials 3, 6, 7, 13, 14, and 20, she did touch one or two of the plates, but after the 20th trial she touched no plates at all. She became more and more inactive from trial to trial; after the 25th

trial she merely sat near Plate 1, turned around, or mewed at the inner door. She usually went directly to Plate 1, settled herself immediately, and made no other movements until she was removed. Naturally, she obtained no reward except on the first trial. As this problem proved to be too difficult for this one kitten, we decided to try the other cats on one of the simpler tasks.

Task 2. Eight kittens were tested on this problem. Three of the animals succeeded in mastering it by the 57th, 63rd, and 82nd trials. The five kittens that finally failed the problem behaved much as did the subject on Task 1. Although they were given from 150 to 200 trials one kitten failed to obtain the reward a single time, 2 failed to obtain it after the fifth trial, one after the 12th trial, and one after the 55th trial. In general, their activity decreased up to the 40th trial, after which there was practically no effort made.

Task 3. This problem was meant to be much less difficult than either of the preceding ones. Only two kittens were tested on it. One of them made four successful trials (9, 10, 41, and 42), but failed completely in trials 43 to 142. After the 42nd trial he never touched Plate 2, although he stepped on Plates 1 or 3 in 15 of the remaining 100 trials. This kitten spent most of his time in climbing the walls of the cage, pawing the inner and outer doors, mewing, running around the inner cage, or merely sitting. The other kitten learned to react to Plate 2 on the 112th trial, after having failed in 30 of the first 70 trials. By the 112th trial he had acquired the habit of going directly to Plate 2 from

the left side (experimenter's left) and pressing it with his left hind foot while facing the inner cage. This series of movements became very definite and precise. Since one of the two kittens failed to learn the problem, it was fairly evident that this task was too difficult to be used in the first approach to the apparatus.

Task 4. Nine kittens were tested on what appeared to be the simplest possible series of problems the box afforded, i.e., stepping on any one of the plates; after this had been learned, stepping on any two plates; and, finally, stepping on all three plates in any order. All of the kittens learned this progressive series. The first step of the series was mastered in 24 to 144 trials, with an average of 42 trials; the second step, in from 2 to 98 additional trials, with an average of 42 trials; the third, in from 14 to 85 trials, with an average of 35.6 trials. The average amount of time spent in the learning of the series was 77, 83, and 24 minutes respectively for the three steps. Since all of the kittens learned to react to the three plates when they took them in a progressive order, we decided to use this general procedure in our experimental work.

TABLE 7

Showing Total Trials, Number of Failures, and Total Time in Minutes

Steps	I			II			III		
Animal	Trials	Failures	Time	Trials	Failures	Time	Trials	Failures	Time
1	34	8	78.2	14	0	3.7	98	1	53.2
2	63	0	40.6	33	0	9.3	48	1	39.7
3	136	0	58.6	51	0	42.8	41	2	36.1
4	49	0	28.5	17	0	5.5	30	0	9.2
5	9	0	12.1	11	1	18.3	32	7	63.1
6	40	11	121.6	11	0	4.3	2	0	.5
7	54	6	79.8	28	0	7.4	56	1	51.6
8	30	4	50.2	25	0	7.7	65	6	77.2
9	134	31	210.7	17	0	5.6	37	0	16.4
10	55	12	115.2	14	1	19.9	27	1	33.9
11	20	0	10.5	57	0	30.4	61	0	45.1
12	35	4	46.6	12	0	2.4	50	0	15.4
13	74	3	57.0	12	0	3.7	22	1	12.2
14	48	3	46.3	37	1	16.6	6	1	10.4
15	16	1	11.6	3	0	.5	53	12	93.4
16	53	3	55.6	27	2	26.3	25	2	19.7
17	31	1	47.4	70	1	36.7	34	1	34.1
18	35	4	55.0	20	0	8.5	71	9	89.8
19	63	2	37.8	1	0	.1	38	1	40.9
20	66	39	238.0	22	1	26.1	71	11	107.2
21	52	33	190.3	3	0	1.1	87	2	48.0
22	20	4	43.9	7	0	1.6	42	0	11.5
23	64	3	44.9	47	0	11.7	11	0	2.5
24	18	0	16.8	30	0	5.1	40	0	9.8
25	39	0	18.4	12	0	6.5			
26	71	6	76.7						
27	59	3	51.4						
28	34	2	28.1	32	1	28.5	7	0	2.0
29	40	1	34.9						
30	115	4	58.8	41	0	16.0	121	13	107.5
31	24	0	15.2						
32	30	0	32.2	10	0	2.7			
33	69	2	42.8	42	1	30.7	45	2	37.1
34	81	1	41.0	41	0	16.7	80	0	22.3
35	68	4	57.9	1	0	.1			
36	42	14	96.4	5	0	2.4	18	0	11.8
51	19	1	22.2	4	0	1.9	1	0	.2
52	43	1	37.3	26	0	11.0	16	0	10.1
53	40	22	138.5	16	2	18.1	21	0	10.2
54	58	29	170.9	21	2	16.3	16	0	5.9
55	34	0	11.6	47	0	16.7	33	3	36.6
56	61	20	152.9	69	7	71.8	23	0	15.9
57	47	7	109.2	1	0	.1	3	0	.7
58	46	0	47.0	26	0	4.8	55	0	13.4
59	40	6	91.8	29	0	8.5	92	1	38.4
60	27	0	18.2	36	0	11.2	28	0	8.1

TABLE 7 (*continued*)

SHOWING TOTAL TRIALS, NUMBER OF FAILURES, AND TOTAL TIME IN MINUTES

Steps	I			II			III		
Animal	Trials	Failures	Time	Trials	Failures	Time	Trials	Failures	Time
61	28	5	61.5	9	0	3.9	21	0	12.5
62	23	1	44.9	27	0	10.0	10	0	3.4
63	18	2	22.3	1	0	.1	4	0	1.3
64	30	3	40.0	6	0	2.7	24	2	24.0
65	58	0	33.6	32	0	13.0	23	0	10.8
66	33	0	21.1	17	0	5.3	22	0	19.9
67	62	6	110.1	6	0	1.3	80	0	15.9
68	36	7	59.4	4	0	1.7	59	1	29.5
69	20	0	13.2	35	0	8.9	56	0	29.4
70	41	8	80.7	10	2	23.1	29	3	26.4
71	23	3	48.6	1	0	.2	1	0	.2
72	52	21	137.5						
73	23	2	35.1						
74	18	0	9.1						
75	17	1	8.7	5	0	2.6	37	1	23.3
76	50	14	131.9	15	0	4.4	35	2	32.1

learned the first step in from 9 to 136 trials, the second in from 1 to 70 trials, and the third in from 1 to 121 trials. The time scores show a large range in the first step, i.e., 8.7 to 238 minutes, but much smaller ranges in the second and third steps, the range for the second being 0.1 to 71.8 minutes, and the third, 0.2 to 107.5 minutes. If we exclude the four extreme scores in each step we find that the range in trial scores in Step I is decreased 48%, the range in Step II, 31%, and that in Step III, 33%; while the range in time scores in Step I is decreased 37%, the range in Step II, 60%, and that in Step III, 29%. These figures show that the wide variability in the several criteria of learning was greatly increased by a few individual animals. This fact should be remembered in connection with the indices of variability shown in Table 9. As a matter

TABLE 8

FREQUENCY DISTRIBUTIONS COVERING TOTAL TRIALS AND TOTAL TIME IN MINUTES

Trials	Steps I	Steps II	Steps III	Minutes	Steps I	Steps II	Steps III
1-3		7	4	0-4		22	8
4-6		6	2	5-9	2	11	4
7-9	1	2	1	10-14	5	5	9
10-12		7	2	15-19	4	8	6
13-15		3		20-24	3	1	3
16-18	5	4	3	25-29	2	3	3
19-21	4	2	2	30-34	3	2	3
22-24	4	1	5	35-39	3	1	5
25-27	1	5	2	40-44	7	1	1
28-30	4	2	3	45-49	5		2
31-33	2	4	2	50-54	2		2
34-36	6	2	2	55-59	7		
37-39	1	1	3	60-64	1		1
40-42	6	3	3	65-69			
43-45	1		1	70-74		1	
46-48	3	2	1	75-79	3		1
49-51	2	1	1	80-84	1		
52-54	4		1	85-89			1
55-57	1	1	3	90-94	1		1
58-60	3		1	95-99	1		
61-63	4		1	100-04			
64-66	2		1	105-09	1		2
67-69	2	1		110-14	1		
70-72	1	1	2	115-19	1		
73-75	1			120-24	1		
76-78				125-29			
79-81	1		2	130-34	1		
82-84				135-39	2		
85-87			1	140-44			
88-90				145-49			
91-93			1	150-54	1		
94-96				155-59			
97-99			1	160-64			
100-02				165-69			
103-05				170-74	1		
106-08				175-79			
109-11				180-84			
112-14				185-89			
115-17	1			190-94	1		
118-20				195-99			
121-23			1	200-04			
124-26				205-09			
127-29				210-14	1		
130-32				215-19			
133-35	1			220-24			
136-38	1			225-29			
				230-34			
				235-39	1		

TABLE 9

RESULTS OF BASIC PROBLEM

	Median	Average	Range	Average deviation	Standard deviation	Coefficient of variability
			Step I			
Trials, *males*	47.50	52.36	9 -136	21.52	29.24	55.84
Trials, females	35.00	36.92	17 - 62	12.88	14.63	39.62
Trials, combined	42.14	46.69	9 -136	17.80	25.28	54.13
Minutes, males	48.30	62.92	10.5-238.0	35.90	52.71	83.78
Minutes, females	45.00	63.85	8.7-170.9	42.53	49.39	77.35
Minutes, combined	47.00	63.31	8.7-238.0	38.73	51.35	81.10
			Step II			
Trials, males	20.00	24.68	1 -70	14.34	17.32	70.18
Trials, females	17.50	20.11	1 -69	13.38	16.48	81.92
Trials, combined	18.50	22.59	1 -70	14.01	17.23	76.27
Minutes, males	8.10	12.96	.1-42.8	9.96	11.75	90.70
Minutes, females	5.80	10.76	.1-71.8	8.70	14.75	137.07
Minutes, combined	7.50	12.05	.1-71.8	9.37	13.05	108.34
			Step III			
Trials, males	42.50	46.47	2 -121	21.96	27.96	60.17
Trials, females	23.75	30.54	1 - 92	18.32	20.81	68.14
Trials, combined	33.75	39.42	1 -121	21.91	27.37	69.43
Minutes, males	33.75	38.02	.5-107.5	24.78	30.89	81.24
Minutes, females	14.50	17.28	.2- 38.4	9.30	11.03	63.83
Minutes, combined	19.20	28.46	.2-107.5	20.07	26.45	92.93

of fact, the majority of animals representing each step are grouped fairly close together in spite of the rather wide deviations shown in Table 9.

The measures of central tendency and variability for the several steps of the basic problem are given in Table 9. The group averages show that Step II was the easiest for the kittens, and Step III next. Step II was reliably easier than either Steps I or III, both in terms of trial and time scores, as indicated in Table 10. The chances of a true difference greater than zero between Steps II and I or between Steps II and III was

TABLE 10

RELIABILITY OF THE DIFFERENCE BETWEEN AVERAGE SCORES OBTAINED ON STEPS I, II, AND III OF THE BASIC PROBLEM AND BETWEEN MALES AND FEMALES ON A GIVEN STEP

Groups	Difference	$S.D._{diff.}$	Difference / $S.D._{diff.}$	Chances in 100 of a true difference greater than 0
		Trial Scores		
I-II (both sexes)	24.10	3.96	6.08	100.00
I-III (both sexes)	7.27	4.97	1.46	93.00
II-III (both sexes)	16.83	4.45	3.78	100.00
I, males-females	15.44	5.65	2.73	99.71
II, males-females	4.57	4.60	.99	84.00
III, males-females	15.93	6.77	2.35	99.05
		Time Scores		
I-II (both sexes)	51.26	6.75	7.60	100.00
I-III (both sexes)	34.85	7.50	4.65	100.00
II-III (both sexes)	16.41	4.06	4.04	100.00
I, males-females	.93	13.06	.07	53.00
II, males-females	2.20	3.69	.60	73.00
III, males-females	20.74	6.17	3.41	100.00

100 out of 100. According to the time criterion, Step III was reliably easier than Step I, but, in terms of trials required, the chances of a true difference greater than zero between the two scores was found to be only 93 in 100. The relative difficulty of the three steps is further shown by the fact that the average time spent on any trial in Step II was only 0.53 minutes, while that in Step III was 0.72 minutes, and that in Step I was 1.36 minutes.

We have already discussed the matter of the large variability in connection with Table 8. With the inclusion of the extreme scores we see that the ranges were about three times as large as the medians and averages. While the *A.D.*'s and the *S.D.*'s were small-

est in Step II, the coefficient of variability in the second step was somewhat larger than that in Step III and one-and-one-half times the size of that in Step I. This was due, of course, to the difference in the size of the average scores of the three steps.

From Tables 9 and 10 we see that the females required fewer trials on the average to learn each of the steps than the males. The females likewise required less time to master Steps II and III but about the same amount of time to complete Step I. Table 10 shows that in Step III only was there a reliable difference in time scores obtained between the males and females. In Step I the difference was practically zero, while in Step II the chances were but 73 in 100 of a true difference greater than zero existing between the sexes. In terms of trials required to master the problem, the chances were 99.71, 84, and 99.05 in 100 of a true difference greater than zero in favor of the females in Steps I, II, and III, respectively.

The females showed less variability in Step I than the males, but greater variability in Steps II and III, with trials the measure of difference. In terms of time scores, however, the males showed greater variability in Steps I and III but less in Step II than the females. Considering the basic problem as a whole, therefore, we find no consistent trend in variability between the sexes.

Figure 2 shows the average rate of learning the several steps in terms of the time scores. The different forms of the three curves bear out the total trial and time scores in showing that Step II was the easiest for

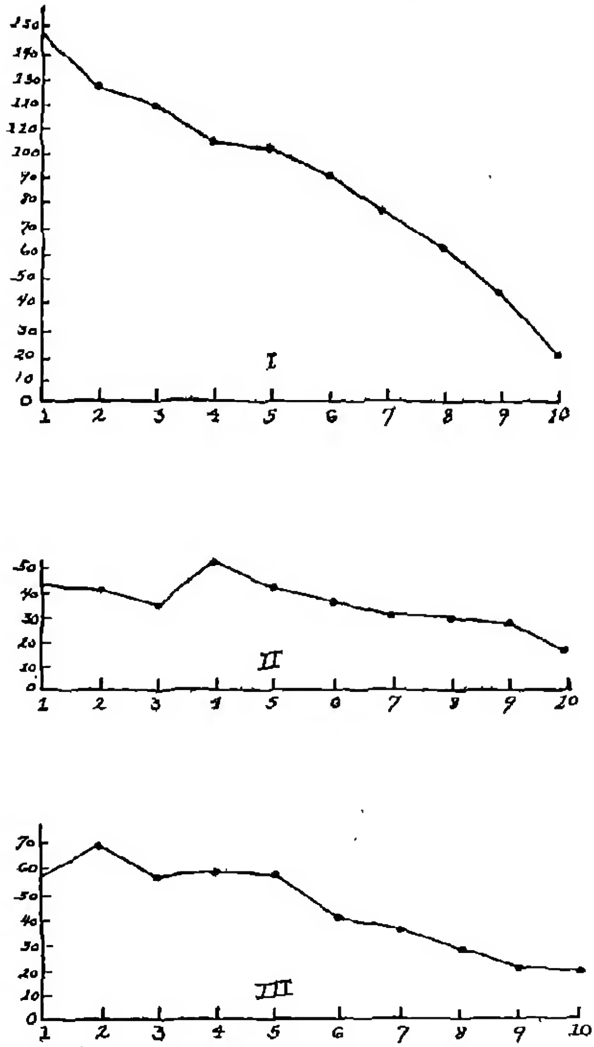

FIGURE 2

THE LEARNING CURVES FOR STEPS I, II, AND III OF THE BASIC PROBLEM

The ordinate in each case represents the time in seconds. The abscissa represents successive tenths of the total trial score. The points on the curve were obtained by dividing the total trials of each animal into tenths and then combining and averaging the time scores for each tenth.

the kittens and Step I the most difficult. The curve representing Step I approaches a straight line, but shows an average drop of about 14 seconds in every tenth. The greatest single drop in Step I, 24 seconds, occurred in the second tenth. The next to the greatest drop, 21 seconds, occurred in the last tenth of the learning process. The curves of Steps II and III start at a point equivalent to that reached in the eighth section of Step I, showing the presence of positive transfer effects. The downward trends were much less than the drop in successive tenths in Step I. The rises occurring in the composite learning curves of Steps II and III must have followed some brief carry-over effects from the preceding step. The carry-over was probably mainly one of motivation, as, toward the end of the learning of a step, the kittens were keyed up to obtaining the food very quickly upon being put into the box. As a result of this set they were not quite as likely to fail in the very first trials of the new problem as they were in the subsequent trials. The failures of a few kittens that temporarily lost interest in the problem after the first few trials were enough to make the average time of the curves rise slightly at one place. In all cases, during the final successful trials of the norm the kittens were performing the required movements very speedily, requiring about 5 seconds in Step I, 8 in Step II, and 10 in Step III.

We will now turn from a consideration of time and trial scores to the number and kinds of errors made and the speed of their elimination in the three steps. As indicated in Table 11, a total number of 3390 errors, or

TABLE 11

SHOWING THE TYPES OF ERRORS* AND THE DISTRIBUTION OF EACH IN STEPS I, II, AND III

Types of errors	Groups of trials 1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-136†	Total
					Step I					
A	12%	8%	2%	3%	2%	2%	0%	0%	6%	6%
B	16	15	11	6	6	2	3	0	4	11
C	13	7	12	12	12	10	8	0	13	12
D	4	6	9	9	7	6	4	3	2	6
E	35	25	24	20	19	15	7	15	13	25
F	20	39	42	50	54	65	78	82	62	40
Total %	100	100	100	100	100	100	100	100	100	100
Total errors	1078	750	600	376	224	151	74	33	104	3390
Total kittens	62	61	50	40	28	18	10	5	3	
					Step II					
A	0%	0%	0%	2%	0%	0%				0%
B	6	3	4	2	0	0				4
C	7	6	3	2	3	8				6
D	0	2	2	4	5	0				2
E	11	5	7	10	0	0				8
F	25	28	36	37	38	41				29
G	37	38	29	26	27	38				34
H	14	18	19	17	27	13				17
Total %	100	100	100	100	100	100				100
Total errors	455	228	164	73	33	26				979
Total kittens	55	33	23	12	6	3				
					Step III					
A	1%	1%	0%	0%	0%	0%	0%	0%	0%	1%
B	5	5	4	5	4	1	0	0	0	4
C	6	12	12	10	4	2	2	0	6	8
D	1	1	4	1	0	0	1	0	0	1
E	7	8	5	4	1	1	0	0	0	6
F	17	14	11	13	14	14	10	4	16	14
G	51	51	56	60	70	70	83	93	76	57
H	12	8	8	7	7	12	4	3	2	9
Total %	100	100	100	100	100	100	100	100	100	100
Total errors	529	421	252	192	109	68	44	23	50	1688
Total kittens	52	43	34	25	18	14	9	6	4	

*The various types of errors were as follows: *A*, climbing walls of cage; *B*, nosing at or clawing outer door; *C*, sitting or washing; *D*, playing with tail, pawing at shadow, jumping, rolling over, rubbing walls; *E*, nosing at or clawing inner door or going back and forth from plates to inner door; *F*, running around inner cage one or more times, without stopping on plate; *G*, stepping on any plate more than once before reacting to the others; *H*, going up to a plate and turning back without actually touching it. If the same error was made more than once in an individual trial it was scored but once.

The number of kittens naturally decreased in successive groups of trials for each step. The actual error scores reflect this decrease.

†For Step III, 81-121.

54.7 per kitten, occurred in learning Step I, which was 1.7 the number of errors made by the average kitten in Step III, and three times the number made in Step II. This difference in the number of errors emphasizes the relative difficulty of the three steps already noted under trial and time scores. If we examine the errors made in Step I, given in the table, we see that there were six types, the most common of which was that of running around the inner cage one or more times without stepping on a plate. Next in importance to this error was that of nosing or clawing at the inner door or going back and forth from a plate to the inner door. Two errors less frequently made were those of nosing at or clawing the outer door, and sitting, or sitting and washing. Playing and climbing the walls of the cage were errors made least often in Step I.

Upon examination of their relative distribution in the successive groups of trials, we see that certain of the errors dropped out early and that other errors grew relatively more and more important. It should be noted in this connection that in the first 40 or 50 trials of Steps I and III and in the first 30 trials of Step II we have the most reliable error records. Beyond these trials the kittens were relatively few in number, and averages based on their records do not indicate the trend of the whole group. For this reason we have lumped together in a single group the errors made in the last trials in each step where only three or four kittens had not learned the step.

The first two types of errors listed in Table 11 were mainly associated with exploration of the box, and, as

they were in no way connected with securing the reward, they dropped out very soon. The error of sitting and washing persisted somewhat longer, though its relative importance did not increase after the first ten trials. The recurrence of this error was due, in part at least, to the fact that several kittens failed in many trials of Step I (see Table 7). This meant that some of them were at length removed from the box after sitting several minutes and therefore developed habits of inactivity, possibly in order to be removed. A few kittens acquired certain habits of rolling over and over, and playing with their tails, etc., but these errors were not, on the whole, significant, even though they were relatively persistent. Probably this latter fact was due to their touching the plates occasionally in their play. The error of reacting to the inner door rather than to the plates was an important one in the first trials of Step I but gradually decreased in importance as indicated in Table 11. That this type of error was important is not surprising since the act of running to the inner door had to be made in every trial immediately before getting the incentive. Hence, in many cases obtaining the reward was associated with running to the inner door rather than with the touching of a plate.

The error of running around the box without touching a plate increased from the first group of trials on until in trials 21 to 60 it was made as often as all other errors combined. The extreme importance of this error may be explained by the fact that the kittens often ran around the box and in the process touched a plate and received the reward. During many trials, perhaps, a

number of kittens merely were conditioned to running around the box rather than to stepping on a plate. For they would start on the run around the box as soon as they were put at the entrance, and, if the door did not open the first time, they would often stop momentarily at the inner door and then make the run again and again until a plate was hit in the excursion and the door opened. The persistence of this error and the dropping out of errors less closely connected with the act of securing food bear out Kuo's (16) finding that the more irrelevant acts drop out before the less irrelevant ones.

The first five types of errors listed in Table 11, which made up 60% of the errors in Step I, were made only 20% of the time in Steps II and III. This means that behavior unrelated to movements required in the solution of the problem, such as climbing the walls of the cage, sitting, washing, clawing and nosing the doors, and playing, played but a minor rôle in the learning of the second and third steps. The sixth error, that of running around the box without touching the plates, likewise occupied a less important place in Steps II and III than in Step I, and a less important place in Step III than in Step II. Since the kittens were used to reacting to one plate by the time they had finished Step I, and used to reacting to two plates at the end of Step II, then, in advancing from one step to another, they would be less and less likely to run around the box without touching one of them at least.

Besides the errors made in Step I there were two other types of errors that appeared in the learning of Steps II and III. These were stepping on any plate

more than once before reacting to the other one or other two, and going up to a plate and turning back without actually touching it. The second of these was due to the kitten's turning too quickly before he touched the plate, an exaggerated form of Type E, only with excursions nearer the plates. This type of error was not so common as that of touching one plate more than once. About one-third of the errors of Step II and more than one-half of the errors of Step III were of this latter type. In Step I the kittens were used to having the door open when they touched a single plate, so, when in Step II the door did not open when this plate was touched, the reasonable thing to do, perhaps, was to touch it again. If in Step I they always went to a particular plate, they would be more likely to keep repeating this movement in Step II than if, in learning Step I, they sometimes went to one plate and sometimes to another. The fact that this error occupied a bigger place in Step III than in Step II was due, no doubt, to the chances being greater in Step III of touching a plate already reacted to. For, after touching two plates, the kitten could go back to the first one touched or to the second one. In Step II, after touching one plate, there would be the alternative of touching one of the other two plates, either of which would be a correct response, or touching again the one just reacted to. A more complex set, therefore, had to be maintained in Step III than in Step II. As an aid in maintaining the set in Step II the kitten could probably see two plates at once, whereas in Step III he likely could not see all three at any one time.

As seen in Table 7, there were many more failures made in Step I than in Steps II and III. The number of trials on which failure was recorded were as follows: Step I, 0-39; Step II, 0-7; and Step III, 0-13. In terms of trials required to solve the steps, 13% were failures in Step 1, 2% were failures in Step II, and 3.8% in Step III. The reasons for the difference in the number of failures made in the three steps may be found in the types and number of errors in the several steps. The fact that more errors were made per trial in Step I was probably due to getting used to the box, when the habit of obtaining a reward had not been so well established.

A slight sex difference is found in the number of failures made. In Step I, for example 11% of the trials of the males and 16.5% of the trials of the females were failures. In Step II, 1.1% of the trials of the males and 3% of the trials of the females, and in Step III, 5.5% of the trials of the males and 1.9% of the trials of the females were failures. As noted above, failure on any trial meant five minutes spent in the box. The fact that the percentage of failures was greater for the females in Steps I and II than for the males explains in part why the total time required on these steps was not less for the females when their total number of trials was considerably less.

The number of failures made by a kitten in the first and third steps may be taken as a general indication of their relative success in learning the two steps. Since only one kitten failed more than twice in Step II, the number of failures in this step cannot serve as such an

indicator. In Step I, however, we find that the highest quartile of kittens, in terms of trials required to solve the step, failed 4.96% of the time, that the second quartile failed 10.15%, the third quartile, 15.29%, and the lowest group, 19.37% of the time.

In Step III the highest quartile failed 2.09% of the time; the second quartile, 2.23%; the third quartile, 5.17%; and the fourth quartile, 4.3% of the time. While there were relatively fewer failures in the lowest quartile than in the next lowest, when we compare the upper and lower halves of the whole group we find that the former failed but 2.16% of their trials, while the latter failed 4.27% of the trials.

The plates were reacted to in a variety of ways in Step I. They were as follows: (*a*) stepping on the plate with the fore paws or clawing the wires of the plate, thereupon turning back to the inner door, (*b*) running or walking across the plate and touching it with most of the feet, (*c*) touching it with one or both hind feet only, (*d*) falling on the plate, (*e*) playing on it, (*f*) touching the plate with the nose, and (*g*) sitting on the plate. The majority of the kittens, i.e., about 80% of them, took either the first or the second methods. The third method was taken next often, but all the other four methods were employed no more than 4% of the time.

In general, the poorer kittens were more likely to take the second and third methods in Step I than were the better ones. The poorest quartile, for example, reacted in the first manner 35.47% of the time; the third quartile, 46.41%; the second, 59.65%; and the highest

quartile, 61.34% of the time. The poorest quartile took the second method in Step I 40.62% of the time; the next quartile, 30.53%; the second quartile, 24.84% and the highest quartile, 24.87% of the time. Again, the poorest quartile took the third method 20.80% of the time; the third quartile, 16.45% of the time; the next quartile, 10.97%; and the highest quartile, 11.43% of the time.

Since the females took fewer trials on the average to learn the first step than did the males, we would expect them to have more often used the superior method of reacting to the plates. This they did 54.56% of the time, while the males took it 49.41% of the time. The females likewise used the second method less often than the males, but the poorer females took the third more often than the poorer males. This was due to the fact that one female, No. 56, very early developed the habit of touching the plates with her right hind foot. The others rarely did this.

The movement of touching the plate with the fore feet and then turning back, rather than going on around the box or touching the plate with the hind feet, would seem to be the superior method in Step I, even though we did not know that the better kittens were more likely to take it. In the first method, more precise movements were made, the kitten was not so likely to pass over the plate, and a closer connection was made between the act of stepping on the plate and securing the reward. On the other hand, in touching the plate with the hind foot the kitten often would not make a precise reaction to the plate but rather would grope for it, moving back

and forth in front of the plate, pushing back, but many times not actually touching it.

The method of touching the plate with the hind feet only was used by cat No. 56 about 85 to 90% of the time in Steps II and III, but very rarely by any other kitten. In fact, the first two methods mentioned were used almost entirely in Steps II and III. In the second and third steps the kittens began to use the second of the methods more frequently than the first. In Step II the plates were touched by the first method 47% of the time and by the second 52% of the time. In the third step the plates were touched 32% of the time by the first method and 67% by the second. The increased preference for the second method over the first was to be expected in Steps II and III as it would be obviously inefficient to come back to the inner door after touching one plate before going on to another. Furthermore, if the kitten turned back to the inner door after touching a given plate in Steps II and III, it would be more likely to touch the same plate again than if it continued in the same direction. It is not surprising, therefore, that in Step III the better kittens were more likely than the slower ones to use the second method, nor is it surprising that the second method was more regularly taken in the latter half of Step III than in the first half.

In Step I there seemed to be but slight preference for the right direction over the left, as indicated by the path the kittens took when they were started from the outer door. The former direction was taken 52.77% of the time and the latter 47.23% of the time. The

lowest quartile took the right direction 59.85% of the time, while the three upper quartiles took it from 49 to 51% of the time. Since these indices do not differ greatly, it did not seem necessary to work over the data of Steps II and III to find whether one direction was more favored than another in these steps.

There did, however, seem to be a preference for certain of the plates in Step I. Plate 1 was touched about one-half the time; Plate 2, one-sixth of the time; and Plate 3, about one-third of the time. In general, the poorer kittens were more likely than the better ones to touch Plate 2, the latter being more likely to go to Plate 3. While there was but a slight difference in the relative number of reactions to Plate 1, Plate 2 was touched by the lower half of the group 20.99% of the time and by the better half, 13.90% of the time. Plate 3, on the other hand, was touched 29.51% of the time by the poorer group and 38.86% of the time by the better one. The females reacted to Plates 2 and 3 less often than the males, and more often to Plate 1.

The kittens were not very consistent in the selection of plates in Step I. The males and females, better and poorer kittens, all went about the same percentage of the time to one special plate, i.e., 56.7%. In other words, some one plate was favored by a kitten so that he would go to it more than half the time and to the other two combined less than half the time. The eight poorest animals in Step II went to a particular plate on the average of 75% of the time during the last ten trials of Step I. The eight best kittens went 63% of the time to one plate in the last ten trials of Step I. The

difference between these groups indicates possibly that those that were most likely to go to a particular plate in the final learning of Step I would be slower than the others in the learning of Step II. We find, on the other hand, that the better kittens in Step III were those that more often took one direction only in the last 10 trials of Step II, although they did not always touch the same two plates from trial to trial.

We find no reliable correlation between the ranking of a kitten in one step and another of the basic problem by the Pearson method. The correlations obtained are as follows: Steps I and II, 0.252 ± 0.086; Steps I and III, 0.18 ± 0.09; Steps II and III, 0.064. This means that the ability of a kitten to master one step in the basic problem cannot be predicted from its score on another one. Nor does there seem to have been much relation between the number of failures made by a subject in one step in the basic series and another. In Step II, for example, only one cat failed more than twice. This cat, No. 56, failed Step I 20 times, Step II 7 times, and Step III 0 times. Only six kittens failed Step III more than 2 or 3 times. The failure records of these kittens on the three steps are as follows: cat No. 5 failed in Step I 0 times, in Step II once, and in Step III 7 times; No. 8 failed in Step I 4 times, in Step II 0 times, and in Step III 6 times; No. 15 failed in Step I once, in step II 0 times, and in Step III 12 times; No. 18 failed in Step I 4 times, in Step II 0 times, and in Step III 9 times; No. 20 failed in Step I 39 times, in Step II once, and in Step III 11 times; No. 30 failed in Step I 4 times, in Step II 0 times, and in Step III

13 times. While the kittens in general cannot be said to have been consistently good or bad in the several steps nor to have regularly gone to any one plate, they did tend to go in one direction and to step on the plates in the same way from one trial to another.

Summary. At the rate of ten trials a day, it took the average kitten about 10 days to learn the several steps of the basic problem. No kitten failed to learn any one of the steps. Step II was the easiest and Step I the most difficult, judged by all our available measures, namely, trials, time, failures, and errors. The females were found to be somewhat superior on most of these counts.

The wide variability present in the learning of the steps was found to be due mainly to the presence of several extreme cases. A few kittens were exceptionally slow in mastering the correct procedure and in eliminating excess movements. Several of these developed bad habits which the average and superior subjects did not. For example, one animal chased its tail in many trials, going round and round after it as soon as it was put in the box. Another kitten rarely touched the plates with any but the right hind foot, making many errors in sliding back and forth in front of the plate before touching it. Some kittens took a long time to get started learning the first step because they steadfastly avoided touching the plates in the early trials, while others acquired the habit of rushing around the inner cage, sometimes touching a plate but many times missing some or all of them. Two kittens may not have been as well motivated as the others. One of

these, the slowest of all kittens when the trials of all three steps are added together, never ate meat, so was only rewarded by milk. The other kitten, the third poorest, had a sore foot for a part of the time.

In general, the kittens that learned the steps in the shortest time made slower and probably more precise movements, were more likely to take a single direction from trial to trial, used more often a superior method of reacting to the plates, were less likely to touch Plate 2, and more often faced the inner door as they touched a plate. No kitten was noted as having learned a step "suddenly" in the sense of having made a series of perfect performances immediately following a first chance success. In a few cases there were, however, as few as six to ten random successes preceding a series of from five to nine perfect trials. In all of these situations the kittens were facing the inner door as they touched the plate accidentally and probably saw the door slide back. Sometimes they went immediately to the reward and sometimes they continued to play at the plate, pulling at the wires or pushing the paws under the plate.

If we add up the trials required to learn the three steps by each kitten and compare the results, we see that three kittens took from 21 to 30 trials (2 to 3 days for all the steps), 14 from 51 to 80 trials, 17 from 81 to 120 trials, 14 from 121 to 170 trials, 3 from 181 to 230 trials, and one, 271 trials. Therefore, although we found no reliable correlation between a kitten's standing on one step and another, there is no doubt but that some of the kittens were superior to others, generally, in the solution of the basic problems.

V

RESULTS OF THE ADVANCED PROBLEMS

Advanced Problem A. The first of the advanced problems was simply a continuation of the steps of the basic problem. Just as in the basic problem, there was no specific order required in the various steps, the general problem being to learn to react to as many plates as possible, step by step. Therefore, as soon as a kitten learned to touch the three plates in Step III, it was put on Step IV, in which four plates must be touched, then on Step V, in which five plates must be reacted to, then Step VI with six plates, etc., until the animal could advance no farther. In this way the limits of its ability were measured by the number of plates that it could react to in securing the food.

In Step IV of this problem the inner door opened if, after having touched three plates, the kitten stepped on a fourth plate which was different from the last one touched. For example, the inner door opened after the kitten reacted to plates 1-2-3-1 or 1-2-3-2, but it did not open if the series was reacted to in this way, 1-2-3-3. As in Step III, the kitten could begin at any one of the plates from trial to trial and could proceed in either direction. In Step V, another plate must be added with the same provision. In this step the three plates must be touched first and then two of them again, for example, 1-3-2-1-3 or 3-2-1-2-3. In Step VI, another plate must be added which meant that the kitten must touch all three plates once and then once again, as for example, 3-2-1-3-2-1, or 3-2-1-2-3-1, or 3-2-1-3-1-2, etc. The

problem was continued in this way so that if they mastered all the steps up to Step IX they must now touch the plates all once, then once again, and then again. In Step XII the rounds must be made four times instead of three.

In every step the kittens were shocked only when they touched again a plate just reacted to. The reward was accessible to the subject after all the necessary plates were touched in a given step. However, the individual trial was not considered perfect unless the act was performed without reacting to other plates. Errors consisted in touching the plate last reacted to again, in going around the inner cage without reacting to the plates, and in numerous types of excess movements. It should be noted that such conditions as the time allowed per trial, the norm of mastery required, the incentives, etc., were the same for the advanced problems as for the basic one.

Two kittens were used for determining the strength of current that should be used for shocking the animals in the advanced problems. The e.m.f. set at 1000 volts with a current reading of 0.10 m.a. was found to produce a too intense shock. After a few trials the kittens would do nothing but sit in the problem box even though they had been previously trained to react to all three plates. When the kittens had been given further training on the basic problem to renew their activity they were tested on the first step of the advanced problem again. At this time the e.m.f. was set at 750 volts and was gradually lowered to 400 volts. At the latter voltage the current reading was 0.04 m.a. We finally

TABLE 12

SHOWING AGES OF ANIMALS USED IN THE VARIOUS STEPS IN ADVANCED PROBLEM A

Animal	Age in weeks at beginning of steps: IV	V	VI	VII	VIII	IX	X	XI	XII
11	12	12	13	17	21	23			
12	12	12	12	15	18	18	19	20	21
13	12	13	13	14	21	23	23	24	
14	12	13	15	19	21	25			
56	12	17	17	20	20	20			
57	10	11	11	12	13	17	19	23	
58	12	12	13	14					
59	12	13	14	15					
60	11	12	12	13	15	15	16	16	18
Av.	11.7	12.8	13.3	15.4	18.4	20.1	19.3	20.8	19.5

decided to use this amount of voltage in our experiment proper. The experimenter could barely feel the prick of the shock on the back of the hand at this strength and not at all on the palm. It was enough, however, to make the kittens lift up the paws and occasionally shake them, or touch the plates more lightly than they had in the basic problem. At the same time the shock was not severe enough to cause the animals to avoid the plates.

As soon as the kittens learned the basic problem they were put on one or another of the advanced problems. There was no attempt to select them on the basis of their ability to learn the first problem. Four males and five females were trained on Problem A, as will be seen in Table 12. Since a general description of each is given in Table 6, it is not repeated in this table. On the average, they were a little less than three weeks older at the beginning of Problem A than at the beginning of the basic problem. It will be seen from Table 12 that the age range increased somewhat in the latter

steps of Problem A, such increase, of course, following from the different rates of learning. In none of the steps, however, was the difference in age greater than two months.

Records covering the total trials, failures, and the total time required by the individual animals on the various steps in Problem A are given in Table 13. In

TABLE 13

SHOWING INDIVIDUAL SCORES IN TRIALS, FAILURES, AND TIME FOR THE VARIOUS STEPS IN ADVANCED PROBLEM A

	Order of steps								
Animal	IV	V	VI	VII	VIII	IX	X	XI	XII
				Trials					
11	2	61	236	322	117	F*			
12	12	13	196	147	43	47	60	58	F
13	70	17	30	522	80	26	69	F	
14	120	102	243	164	326	F			
56	275	17	184	8	13	F			
57	49	2	1	71	234	163	299	F	
58	5	83	38	173					
59	72	23	67	16					
60	69	12	2	138	2	21	8	146	F
				Failures					
11	0	0	3	4	2	F			
12	1	0	0	0	0	0	0	1	F
13	1	0	0	2	0	0	3	F	
14	0	0	0	0	7	F			
56	24	0	2	1	0	F			
57	0	0	0	0	5	1	64	F	
58	0	0	0	0					
59	0	0	4	0					
60	0	0	0	3	0	0	0	25	F
				Time in minutes†					
11	0.5	48	212	378	138	F			
12	11	8	120	95	46	45	58	88	F
13	40	7	10	362	53	26	72	F	
14	43	54	129	99	354	F			
56	420	10	128	11	10	F			
57	26	0.7	0.3	53	305	229	629	F	
58	2	30	21	135					
59	36	12	77	9					
60	18	4	1	129	3	18	7	310	F

*F means that the animals finally failed the step.

†The time records, except where the total is less than one minute, are given to the nearest minute.

the next two tables the measures of central tendency and variability for the males and females and for the sexes combined are given. It will be noted from these tables that the ranges are great in all the steps, varying usually from fewer than 10 trials to more than 200. Step V seems to have been the easiest of the series, then Steps IV, VI, VIII, and VII in order. Beginning with Step IX we find some of the animals failing altogether, and on the twelfth step all of them failing. While the learning limit of the average kitten seems to have been about Step VIII, i.e., reacting to eight plates without error, some went beyond that point and two of them were able to master Step XI.

Since few animals were used on Problem A, any obtained sex difference is not significant. It may be noted, however, that of the two kittens that were advanced the farthest, one was a male and one a female. In general, the records of the females were superior to those of the males up to the point where some animals of both sexes began to fail.

As noted above, the errors that occurred in the learning of Problem A were mainly of two types, going by the plates without touching them and turning back to a plate and touching it again before reacting to the other two. These errors correspond most closely to Types F and G present in the second and third steps of the basic problem. Other errors found in the basic problem were rarely present in Problem A, at least in the first four or five steps. The habit of sitting in the problem box was developed almost entirely in the last trials of the more difficult steps—usually those on which

TABLE 14

SHOWING MEDIANS AND RANGES* IN TRIALS AND TIME OF MALES AND FEMALES FOR THE VARIOUS STEPS IN ADVANCED PROBLEM A

	Males				Females			
	Trials		Time		Trials		Time	
Steps	Med.	Range	Med.	Range	Med.	Range	Med.	Range
IV	41	2-120	25	.5-43	69	5-275	26	2 -420
V	39	13-102	26	7 -54	17	2- 83	10	.7- 30
VI	215	30-243	124	10 -212	38	1-184	22	.3-128
VII	243	147-522	230	95 -378	71	8-173	53	9 -135
VIII	98.5	43-326	96	46 -354	13	2-234	10	3 -305
IX	36.5	26- 47	36	26 - 45	92	21-163	106	18 -230
X	64.5	60- 69	65	58 - 72	154	8-299	318	7 -629
XI	58		38		146		310	88 -310

*The medians and ranges are based only on the scores of those kittens that eventually learned the steps. Except where the total is less than one minute the time records are given to the nearest minute.

the animals finally failed. We see from Table 14 that the average length of each trial was very little longer than that in Step III, although the number of movements increased from step to step.

In the various steps the poorer kittens seemed to show the presence of the two errors mentioned above more regularly than the others. For example, No. 14, usually the last to learn a step, as will be seen in Table 13, would run around the box many times without touching a plate, often requiring seven or more trips around before the plates were touched properly and the reward obtained. Kitten No. 13 required as many as 522 trials to learn Step VII. In half of these he ran around the box first without touching a plate, although in later excursions of the same trial he seldom failed to react to each plate as he came to it.

A slight variation of this first type of error was the avoidance of a particular plate one or more times in a trial. We find three kittens, for example, that often

TABLE 15

SHOWING MEASURES OF CENTRAL TENDENCY AND VARIABILITY IN TRIALS AND TIME FOR THE VARIOUS STEPS IN ADVANCED PROBLEM A

Steps	Median		Average		Range		Average deviation		Standard deviation		Coefficient of variability		F*	L*
	Trials	Time	Trials	Time	Trials	Time	Trials	Time	Trials	Time	Trials	Time		
IV	69.1	26	74.9	66	2-275	0.5-420	54.5	78	79.6	126	106.2	190	0	9
V	17.0	10	36.7	19	2-102	0.7- 54	30.2	16	33.7	19	91.8	97	0	9
VI	67.0	77	110.8	78	1-243	0.3-212	92.4	62	96.3	70	86.9	91	0	9
VII	147.0	99	173.5	141	8-522	9.0-378	124.2	114	161.4	137	93.0	97	0	9
VIII	80.0	55	116.3	130	2-326	4.0-354	109.1	134	121.3	144	104.0	112	0	7
IX	36.5	35	64.2	80	21-163	18.0-230							3	4
X	64.5	65	109.0	191	8-299	7.0-628							0	4
XI	102.0	199	102.0	199	58-146	88.0-310							2	2
XII													2	0

*In the column under F is listed the total number of kittens that failed a given step. In the column under L is listed the total number of kittens that learned a given step. The time records, except where the total is less than one minute, are given to the nearest minute. The measures are based only on the scores of those kittens that eventually learned the steps. As will be seen, none of the kittens learned Step XII.

The more precise measures of variability were not computed where the number of animals was less than 7.

omitted one plate, particularly in the steps which they mastered only after many trials. Kitten No. 56, still reacting more than 80% of the time with her right hind foot as in the earlier steps, developed the habit of avoiding Plate 3 the first time around in Step IV, as did kittens No. 11 and No. 12 in the sixth and seventh steps. The second type of error mentioned above, that of turning back and touching a plate again, was made by No. 57 beginning with the eighth step and by Nos. 58 and 60 in Step VII.

In general, the kittens that learned the individual steps more quickly than others and advanced farther in the learning of the problem appeared to move rather more slowly and precisely than the average. They also showed more consistency in keeping to one direction, rather than going first one way and then another. In some of their less successful trials we noted that they tended to reverse the direction more often than in their perfect trials. Several kittens appeared merely to touch one plate after another until the inner door opened but did not have a general set for a certain number of them. They would go to one plate and hesitate, then to another, and possibly turn the head in the direction of the door, and keep up this sort of behavior until the reward was obtained. Others, however, especially when the step was nearly learned, would react to the plates as a group and behave differently to the same plate on various trips around the box. For example, one kitten in the seventh step would always stop a moment after touching the third plate and mew or turn his head in the direction of the inner door

and would then go on without hesitation until he came to this plate again. This kitten, however, would not hesitate on Plate 3 the first time around, but the more times he needed to go around the box, the longer did he seem to hesitate on this plate. In this step Plate 3 happened to be the first and last touched in the series more often than the other plates, and there seemed to be no doubt but that the same plate was not reacted to in the same way in various parts of a given trial.

With the addition of movements to be made from step to step, the first movements became farther and farther removed from the act of securing the reward. Hence, after an excursion or two around the box without results, the kittens often began to sit for a time and then to repeat the same thing again. The kittens became less and less active until they would make only one excursion around the box, possibly touching one or two of the plates on the way. At the end, however, some of them would not do even this. Only one kitten kept up her general activity, often actually securing the reward, up to the 1200th trial, even though she was unable to master this step.

Advanced Problem B. The kittens that were put on problem B were required to react to the plates in a certain definite order, instead of merely adding some other one plate as the kittens had to do in Problem A. We found that by the time the kittens had completed Step III of the basic problem they were consistently going in one direction, either to the right or to the left. In Step IV of Problem B the kittens were required to reverse this direction. If they had previously touched

the plates in the order of 1-2-3 or 2-3-1 in Step III, they must now touch them in the order of 3-2-1, while if they had learned in Step III to touch them in the order of 3-2-1 or 2-1-3 they must now touch them in the order of 1-2-3. Before we decided on this procedure we thought we could set up an exact reversal of direction, such as requiring them to react to 1-3-2 if they had previously learned 2-3-1, or to react to 3-1-2 if they had learned 2-1-3 in Step III. As three kittens could not master this exact reversal order, we decided to try it no more, but to use the more simple one of 3-2-1 or 1-2-3, depending on the general direction the animal had taken in the final mastery of the third step of the basic problem.

The correct responses for the various steps in Problem B, including the direction taken in the last part of Step III are as follows:

Step	III	3-2-1	or	1-2-3
Step	IV	1-2-3	or	3-2-1
Step	V	1-2-3-2	or	3-2-1-2
Step	VI	1-2-3-2-1	or	3-2-1-2-3
Step	VII	1-2-3-2-1-3	or	3-2-1-2-3-1
Step	VIII	1-2-3-2-1-3-1	or	3-2-1-2-3-1-3
Step	IX	1-2-3-2-1-3-1-2	or	3-2-1-2-3-1-3-2

It will be seen that Step IV involved merely the reversal of Step III. From this point onward, each step required the addition of one more plate to the series already learned. Steps IV, V, and VIII may be said to be the crucial ones, since in each of these new direction habits had to be set up. In Step IV the animal must begin the series at Plate 3 instead of at Plate 1, or vice versa. In Step V he must turn back after touching the three customary plates so as to avoid the first plate touched. In Step VII the animal must continue in

front of the door to the last plate of the series instead of turning back and repeating Step VI. In Step VIII *he must make a third reversal in touching the last plate of the series.* In every step of the problem the same strength of current as used in Problem B was administered when the kittens touched a plate while going in the wrong direction. They were never shocked when they were taking the correct path, even though they may have omitted plates. In case of omissions they were not allowed to receive the reward until the plates had later been touched in the required order.

As may be seen from Table 16, 9 males and 4 females were given training on Problem B. Their ages at the beginning of the problem ranged from 10 to 12 weeks and at the end of it from 29 to 57 weeks, depending on how many steps had been mastered. Table 17 includes the individual records of the kittens on this problem in

TABLE 16

SHOWING AGES OF ANIMALS USED IN THE VARIOUS STEPS IN ADVANCED PROBLEM B

Animals	Age in weeks at beginning of steps: IV	V	VI	VII	VIII	IX
1	11					
2	11	17	32	33	40	42
3	12	19				
4	12	17				
5	10					
6	11	14				
7	11	19				
8	11	20	31	33		
9	12	17				
51	10					
52	10	22				
53	12	16				
54	11	13				
Av.	11.1	17.4	31.5	33		

TABLE 17

Showing Individual Scores in Trial, Failures, and Time for the Various Steps in Advanced Problem B

Animal	IV	V	VI	VII	VIII	IX
			Order of steps			
			Trials			
1	54					
2	371	1030	54	491	130	F
3	505	F*				
4	266	F				
5	255					
6	181	F				
7	376	F				
8	568	741	166	F		
9	261	F				
51	144					
52	824	F				
53	281	F				
54	117	F				
			Failures			
1	0					
2	0	3	0	1	3	F
3	34	F				
4	5	F				
5	32					
6	1	F				
7	0	F				
8	63	56	4	F		
9	25	F				
51	0					
52	8	F				
53	15	F				
54	7	F				
			Time in minutes†			
1	36					
2	167	428	16	232	114	F
3	564	F				
4	120	F				
5	396					
6	130	F				
7	153	F				
8	525	625	69	F		
9	274	F				
51	64					
52	274	F				
53	217	F				
54	104	F				

*F means the animal finally failed the step.
†The time records are given to the nearest minute.

terms of total trials, failures, and time. As shown in Table 17 and in the two succeeding ones, Step IV was a difficult one and Step V was seldom mastered. The average number of trials required in the mastery of Step IV was 323 ± 202, the range being from 54 to 824. All but two of the kittens that were put on Step V failed in the 1200 to 1500 trials given them. The two successful kittens required 741 and 1030 trials to learn Step V but succeeded in mastering the sixth step in relatively few trials as is shown in the tables. One of the two failed the seventh step, but the other mastered it after 491 trials. The eighth step was easier for this one surviving cat, now almost an adult, as he required only 130 trials. While he succeeded in passing a norm of 7 out of 8 trials he never reached a higher norm on Step IX and was finally considered to have failed at this stage. Sex differences obtained on this problem are not significant, at least as far as the fourth step is concerned. The two kittens that succeeded in going beyond the fourth step were both males.

Two types of errors were commonly made in the learning of Step IV. These were taking the wrong direction and omitting one or more of the plates. The poorer kittens made these errors a greater percentage of the time than the others did. The first of these errors was made in less than 10% of the trials of the better kittens after the 150th trial, whereas it was made in 35% of the trials of the poorer group after this point. The best of the kittens seemed to go slowly and to react somewhat specifically to the plates, the middle group tended to omit the first or second plate in the series

TABLE 18

SHOWING MEDIANS AND RANGES* IN TRIALS AND TIME OF MALES AND FEMALES FOR THE VARIOUS STEPS IN ADVANCED PROBLEM B

	Males				Females			
	Trials		Time		Trials		Time	
Steps	Med.	Range	Med.	Range	Med.	Range	Med.	Range
IV	266	54- 568	167	36-564	212.5	117-824	160.5	64-274
V	885	741-1030	526	428-625				
VI	110	54- 166	42	16- 69				
VII	491		232					
VIII	130		114					

*The medians and ranges are based only on the scores of those kittens that eventually learned the steps. The records of the one kitten that learned Steps VII and VIII are also given. The time records are given to the nearest minute.

while touching the third. The poorest, however, did not appear to be reacting definitely to any of the plates for they would run quickly around the box time after time, often requiring 5 to 10 trips around the box before the reward was received. The kitten that most often did this, the poorest of them all, would, if she was not removed very quickly upon receiving the reward, go out of the inner cage and run very quickly around the box again and again.

Besides making the usual errors in Step IV, one of the poorest of the kittens exhibited a peculiar type of behavior which kept him from making many perfect trials. The habit of chasing his tail, which developed in the basic problem and which has already been mentioned in that connection, became almost a mania with him in Step IV. Out of the 505 trials spent on the step he chased his tail in 378, first following it time after time in one direction and then in another for as many as 60 times on a given trial without stopping. Usually he would start going around and around as soon as he

TABLE 19

SHOWING MEASURES OF CENTRAL TENDENCY AND VARIABILITY IN TRIALS AND TIME FOR THE VARIOUS STEPS IN ADVANCED PROBLEM B

Steps	Median		Average		Range		Average deviation		Standard deviation		Coefficient of variability		F*	L*
	Trials	Time	Trials	Time	Trials	Time	Trials	Time	Trials	Time	Trials	Time		
IV	266	167	323.3	233	54- 824	36-564	158.1	134	201.9	162	62.4	70	0	13
V	885	526	885	526	741-1030	428-625							8	2
VI	110	42	110	42	54- 166	16- 69							0	2
VII	491	232	491	232									1	1
VIII	130	114	130	114									0	1
IX													1	0

*In the column under F is listed the total number of kittens that failed a given step. In the column under L is listed the total number of kittens that learned a given step. The time records are given to the nearest minute. The measures are based only on the scores of those kittens that eventually learned the steps. The records of one kitten that learned Steps VII and VIII are also given. As will be seen, none of the kittens learned Step IX.

The more precise measures of variability were not computed where the number of animals was less than 7.

was put into the box, making his way back and forth along the left wall as far as Plate 2 or even Plate 1. Sometimes, however, he would first react to one or two of the plates and then start this play. Outside of the problem box this behavior was never noticed.

The difficulty of Step V lay in making the turn after reacting to the third plate of the series. The eight kittens that failed at this step usually kept on in the same direction but often avoided the plate on which they were shocked either the first or the second time around. It is not surprising that the kittens tended to keep running around in the one direction learned in Step IV. In this step, if the inner door did not open after the animal had made one circuit, he almost without fail repeated the act again and again until the door opened. He merely continued doing this in Step V. The two successful kittens made the turn more and more regularly, until, after the 400th and 600th trials, they usually made it without fail. From then on their errors consisted mainly in the avoidance of one or more plates.

Since Step VI did not require a further turn, but merely the addition of another plate to the series already learned in Step V, it was mastered comparatively readily by both kittens. One of the kittens failed to continue beyond the door regularly enough to master Step VII. As soon as he completed the sequence of 1-2-3-2-1 he would repeat it again or a part of it again. After about 700 trials he became more and more inactive and thereafter failed steadily for several hundred trials. The other kitten learned Steps VII and VIII

but finally failed on Step IX after having at one time performed as many as 7-8 trials perfectly. His errors, which were of the same general nature from step to step, were as follows: starting out on the wrong plate (which was especially frequent in Step VII), continuing two or more times in the order of 3-2-1 before turning back, repeating the sequence of 3-2-1-2-3, or omitting plates while making the proper turns. In Step IX, the new plate which had been added in Step VII was more frequently omitted than the rest, probably because it was out of line with the main trend. To the end of the 1200 trials the kitten retained fairly well the habit of going through most of the movements involved in a perfect trial, although he failed to make the more specific movement of touching off the plates in more and more of them. This kitten from the learning of the fourth step on would make the necessary movements, usually without delay, and would hesitate after touching the last of the series. The perfect trials in Step IX were often performed in 15 seconds or less.

Advanced Problem C. This problem differed from Problem B in that a fixed direction had to be maintained instead of a reversal of direction at the critical points. That is, at Steps IV, V, and VIII the animal must continue on around the inner cage instead of reversing its direction. For example, in Step IV of Problem C the animal must step on the plates in this order, 3-2-1-3 if in Step III of the basic problem it had reacted to them in the order of 3-2-1. The correct responses for the various steps in Problem C, including the direction taken in Step III, are as follows:

Step	III	3-2-1	or	1-2-3
Step	IV	3-2-1-3	or	1-2-3-1
Step	V	3-2-1-3-2	or	1-2-3-1-2
Step	VI	3-2-1-3-2-1	or	1-2-3-1-2-3
Step	VII	3-2-1-3-2-1-3	or	1-2-3-1-2-3-1
Step	VIII	3-2-1-3-2-1-3-2	or	1-2-3-1-2-3-1-2
Step	IX	3-2-1-3-2-1-3-2-1	or	1-2-3-1-2-3-1-2-3
Step	X	3-2-1-3-2-1-3-2-1-3	or	1-2-3-1-2-3-1-2-3-1
Step	XI	3-2-1-3-2-1-3-2-1-3-2	or	1-2-3-1-2-3-1-2-3-1-2

In this way the plates were added, step by step, until the kittens finally failed on the problem altogether. Just as in Problem B, they were shocked if they touched a plate while going in the wrong direction. Whereas in Problem B they were shocked if they did not make the turns at the critical points, in this problem they were shocked if they did make turns at these points. The animals were never shocked when they were taking the correct path, even though they may have omitted plates. In case of omissions, however, they were not allowed to receive the reward until the plates had later been touched in the required order.

Five males and five females were put on Problem C, as shown in Table 20. Their average age at the be-

TABLE 20

SHOWING AGES OF ANIMALS USED IN THE VARIOUS STEPS IN ADVANCED PROBLEM C

	Age in weeks at beginning of steps:							
Animal	IV	V	VI	VII	VIII	IX	X	XI
15	11							
16	11							
17	12	13	27	27	28	29	30	30
18	12							
19	12							
61	11							
62	11	17	19	20				
63	10	11						
64	10							
65	12							
Av.	11.2	13.7	23	23.5				

TABLE 21

SHOWING INDIVIDUAL SCORES IN TRIALS, FAILURES, AND TIME FOR THE VARIOUS STEPS IN ADVANCED PROBLEM C

Animal	Order of steps IV	V	VI	VII	VIII	IX	X	XI
			Trials					
15	F*							
16	F							
17	31	988	34	77	30	22	7	F
18	F							
19	40							
61	F							
62	416	160	30	F				
63	62	80						
64	F							
65	F							
			Failures					
15	F							
16	F							
17	2	59	0	2	5	7	1	F
18	F							
19	4							
61	F							
62	148	12	1	F				
63	0	2						
64	F							
65	F							
			Time in minutes†					
15	F							
16	F							
17	18	835	14	50	42	42	8	F
18	F							
19	52							
61	F							
62	993	178	26	F				
63	21	41						
64	F							
65	F							

*F means that the animal finally failed the step.
†The time records are given to the nearest minute in every case.

ginning of the problem was approximately the same as that of the kittens at the beginning of Problems A and B. At the end of the problem the ages ranged from about 25 to 47 weeks, depending on the number of steps mastered.

As will be seen from Table 21, six of the kittens failed to master any of the steps of Problem C, while three of them mastered several steps, and one of them as many as seven beyond the basic problem. The range in trials for those succeeding in mastering Step IV was from 31 to 416. The range in time was also large, as will be seen in Tables 21 and 22. While two of the four successful kittens died before they could be taken through more than Steps V and VI, the other two were kept on the problem until they finally failed on Steps VII and XI. It is interesting to note that the kitten that learned more steps than any other one in the problem took 988 trials to learn the fifth step. For other individual records in trials, time, and failures see Table 21, and for general tendencies see Table 22. Two of the four kittens that learned several of the steps were males and two were females. The one that was carried farthest was a male.

The errors made in all the steps of Problem C were mainly those resulting from taking the wrong direction, from omitting plates, and from inactivity. All of these types were characteristic of the behavior of the kittens that finally failed on Step IV. Since in Step IV the kittens had to begin and end on the same plate in every trial they soon began to go mainly to this plate and finally exclusively to it, merely going from it to the inner door and back again. After a number of trials, varying from 30 to several hundred, these kittens would do nothing but sit in the box near the inner door or by the significant plate. At length they were taken from the problem. The kittens that learned Step IV were gen-

TABLE 22

Showing Medians and Ranges* in Trials and Time for the Various Steps in Advanced Problem C

Steps	Males				Females				Combined					
	Trials		Time		Trials		Time		Trials		Time			
	Med.	Range	Med.	Range	Med.	Range	Med.	Range	Med.	Range	Med.	Range	F†	L†
IV	35.5	31-40	35	18-52	239	62-416	507	21-993	51	31-416	37	18-993	6	4
V	988		835		120	80-160	109	41-178	160	80-988	178	41-835	0	3
VI	34		14		30		26						0	2
VII	77		50										1	1
VIII	30		42										0	1
IX	22		42										0	1
X	7		8										0	1
XI													1	0

*The medians and ranges are based only on the scores of those kittens that eventually learned the steps. The time records are given to the nearest minute.

†In the column under F is listed the total number of kittens that failed on a given step. In the column under L is listed the total number of kittens that learned a given step. As will be seen, none of the kittens learned Step XI.

The more precise measures of variability were not computed where the number of animals was less than 7.

erally more active in the box and did not develop the habit of sitting to such an extent as did the others. Step V was somewhat difficult for the kittens that learned Step IV, especially for one. No. 17 would avoid the third plate in the sequence the first time around as he did not have to touch it the second time around. In about half the trials he would fail to react to this plate on the first round.

Since Step VII involved touching the same plate at the end of the trial as at the beginning, one of the kittens grew to making the same sort of errors that she and other kittens made on Step IV, and finally failed it. The other kitten continued without difficulty, adding plates until on Step XI, a step comparable to Step V which he had mastered only after almost a thousand trials. Since he ended his sequence on Plate 2, he was likely to omit Plate 1 in the series of 3-2-1, etc. After a time he would move around the box less often, and finally he would sit near Plate 2 until he was removed.

The reliabilities of the differences between average scores obtained on various steps of the advanced and basic problems are given in Table 23. The records include only the steps on which all kittens were successful. Hence a comparison cannot be made in terms of learning scores beyond Steps VIII in Problem A and Step IV in Problem B. (Actually Step VIII is not included in the table under Problem A, since two of the nine kittens died after learning Step VII.) No comparison at all is possible in terms of trials required to learn Problem C and other problems since many of the animals failed on Step IV in this one problem. Of

course, the point of failure indicates something of the relative difficulty of this and other advanced problems. It is evident from Table 23 that the three advanced problems were not only more difficult than the basic one, although not always reliably so on account of the small number of animals in each of the advanced groups, but that they differed greatly in difficulty from one another.

TABLE 23

RELIABILITY OF THE DIFFERENCE BETWEEN AVERAGE SCORES IN TRIALS OBTAINED ON THE VARIOUS STEPS OF THE BASIC AND ADVANCED PROBLEMS

Groups (both sexes)	Difference	$S.D._{diff.}$	$\frac{\text{Difference}}{S.D._{diff.}}$	Chances in 100 of a true difference greater than 0
AIV-I	28.20	26.7	1.06	85.2
IV-II	52.30	26.62	1.96	97.6
IV-III	35.47	26.79	1.32	90.4
AV-I	10.02	11.67	.86	80.4
V-II	14.08	11.46	1.23	88.6
V-III	2.75	11.86	.23	59.2
AVI-I	64.09	32.25	1.99	98
VI-II	88.19	32.19	2.74	99.71
VI-III	71.36	32.31	2.21	98.6
AVII-I	126.81	57.11	2.22	98.6
VII-II	150.91	57.06	2.64	99.6
VII-III	134.08	57.15	2.35	99.1
AIV-V	38.22	28.8	1.33	90.6
IV-VI	35.89	41.63	.86	80.4
IV-VII	98.61	62.88	1.57	93.7
V-VI	74.11	34.00	2.18	98.5
V-VII	136.83	58.12	2.35	99.1
VI-VII	62.72	65.43	.96	83.2
BIV-I	276.62	56.02	4.94	100.0
IV-II	300.72	56.02	5.37	100.0
IV-III	283.89	56.11	5.06	100.0
BIV-AIV	248.42	61.94	4.01	100.0
IV-AV	286.64	57.09	5.03	100.0
IV-AVI	212.53	64.53	3.29	100.0
IV-AVII	149.81	79.90	1.87	95.7

Since the general experimental conditions and the act of stepping on the plate were the same in all problems, it seems rather evident that the difference in difficulty lay mainly in the type of pattern elements included in the advanced problems. In the first of these problems the progressive complication involved in passing from step to step was not tied up very closely with a definite pattern factor. On the whole, this arrangement appeared to be easier than the others in which the pattern was more definite. The chief difference between Problems B and C was that the former involved a reversal of direction while the latter required the maintenance of the same general direction. In general, the problem involving a change in direction, provided only a single reversal was required, seemed easier than a maintenance of direction at the corresponding step. This is shown by the fact that all the kittens learned Step IV of Problem B while only four out of ten learned Step IV of Problem C. It should be pointed out, however, that a few individual kittens were able to master complex patterns involving a series of reversals or the continuous maintenance of one direction to a point almost as great as did the best individuals in Problem A in which these elements were not involved.

Another point of interest relates to the consistency of the individual in passing from a simple to a complex problem. It is interesting to know whether there is any correlation between the records of the individual on the basic problem as a whole and the scores on the particular advanced problem to which each was as-

signed. It is possible to make certain comparisons bearing on this general problem from the data. For example, by the rank order of merit method we may compare the total score in trials for the three basic steps taken as a whole and the combined scores on the advanced problems up to the point where individuals began to fail. The correlation between the basic scores and the scores on the first four steps of Problem A was $0.14 \pm .22$. The correlation between the basic scores and the score on the first step of Problem B was $0.28 \pm .17$. No correlation may be made between the basic scores and any scores of problem C, for, as we mentioned before, some kittens failed on the first advanced step of the latter. This general lack of consistency, insofar as we can measure it, applies not only to the group as a whole but also to individuals that ranked first in the basic problem and to those that went farthest in the advanced problems. The kitten that ranked first in the basic problem of the group that was later transferred to Problem A also ranked first in the first four steps of the advanced problem and finally failed on Step XI. Kittens No. 12 and No. 60 made the best records in Problem A, in that they mastered Step XI, and ranked third and fourth in their group on the basic problem. The kitten that ranked first in the basic problem of the group whose limits were obtained on Problem B ranked second in the first step of the advanced problem but failed on Step V. Kitten No. 2, that made the best record in Problem B, in that he mastered Step VIII, ranked eighth (out of 10) in his group on the basic problem. The kitten that ranked first in

the basic problem of the group of eight whose limits were obtained on Problem C was one of the six that failed to master the first step of the advanced problem. Finally, No. 17, which made the best record in Problem C, in that he mastered Step X, ranked last in his group on the basic problem. These facts show that one cannot with accuracy predict success in one of the three types of advanced problems from scores on the basic problem.

We have already discussed the probable lack of insight in kittens in connection with the basic problem. It would seem, moreover, that the great number of trials often required by the kittens in the advanced problems and the general lack of consistency of an individual in advancing from one step to another, point to an absence of insight in the solution of the advanced problems.

VI

SUMMARY

1. In the first experiment 52 kittens were tested on a simple or basic problem involving a series of three steps in which no specific order was required. The following conclusions apply to this experiment:

a. All of the kittens were able to learn the three steps involved in this problem.

b. There were no marked sex differences in learning ability, although the females appeared to make better records somewhat consistently.

c. The individual differences were extremely large, the combined score for the three steps varying from 23 in the best animal to 277 trials in the poorest. The average for the group was 94.4 trials.

d. The rank correlations based on the total trials required to learn the three steps were low but positive, being as follows: Steps I and II, $0.25 \pm .086$, Steps I and III, $0.18 \pm .09$, Steps II and III, 0.06.

e. The types of errors varied considerably from animal to animal and from step to step, certain errors tending to be more or less characteristic of the poorer kittens.

2. Some 32 of the kittens, selected at random from the above animals, were divided into three groups and tested on as many advanced problems in order to determine the limits of serial learning of this general sort. These problems were alike in that the complications consisted in adding as many additional steps as possible, but differed from one another in that the

first involved no specific order, the second required a reversal of direction at certain critical points, and the third involved a continuation of direction at these same points. The following conclusions can be drawn from the results on these problems:

a. The first arrangement proved to be the easiest of the three since all the kittens tested were able to add five additional steps as compared with a single additional step in the second problem and none whatever in the third.

b. No consistent sex differences were found on these problems although three out of the four best animals were males.

c. Individual differences were marked. The best animal in each case being able to add eight steps in the first problem, five in the second problem, and seven in the third problem.

d. There appeared to be no consistency in the ranking of a kitten on a simple or basic problem and on the complex problem to which it was later assigned.

e. As in the simple problem, the type of errors varied considerably from animal to animal and from problem to problem, certain errors tending to be more or less characteristic of the poorer kittens.

f. It appears that the limits of learning for this type of performance were actually found under each arrangement, since the following criteria were employed: (1) 1200 trials or more were given before final failure at any step was recorded, provided the animals kept trying, and (2) 100 trials or more were given after the point at which, through constant failure, an animal became inactive.

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LES LIMITES DE L'APPRENTISSAGE CHEZ LES CHATONS

(Résumé)

On a entraîné 82 chatons ordinaires, âgés de huit à neuf semaines, mâles et femelles, avec la boîte à problèmes Jenkins. La boîte s'est composée d'une grande cage de test, diamètre de 135 centimètres, séparée, au moyen d'un écran de fil de fer, d'une petite cage intérieure qui a contenu le stimulant. Sur le plancher de la cage de test ont été trois plaques, 15 centimètres en diamètre, chacune levée d'un centimètre au-dessus du plancher et faites pour donner des chocs électriques. On a espacé ces plaques également dans les trois quadrants autres que celui qui a contenu les portes des deux cages, celle de test et celle du stimulant. Avant que la porte intérieure se soit relâchée, il a fallu que l'animal réagisse en touchant une ou plus des plaques de relâche comme déterminées par l'expérimentateur. Au moyen de trois relais, on a pu ajuster l'appareil de sorte qu'une forme compliquée de réactions ferait ouvrir la porte intérieure. On a fait subir cinq épreuves à tous les chatons le matin et le soir à des intervalles d'environ douze heures. On leur a donné à manger seulement tout de suite après les épreuves. Le stimulant a été des morceaux de boeuf cru et une écuelle de lait. La norme de maîtrise a été neuf épreuves parfaites sur dix. On a permis cinq minutes pour chaque épreuve. On a considéré le problème non réussi seulement après 100 épreuves successives non réussies, ou après 1200-1500 épreuves si les animaux ont continué de faire des essais.

Après des tests préliminaires avec quelques animaux, on a testé 52 chatons avec un problème simple ou fondamental incluant une séries de trois étapes où l'on n'a exigé nul ordre spécifique. Ces étapes ont inclus l'apprentissage à mettre la patte sur une plaque quelconque, sur deux des plaques, et sur toutes les trois plaques. Tous les chatons ont pu apprendre les trois étapes. Les femelles ont réussi un peu mieux. Les différences individuelles ont été grandes. Le résultat combiné des trois étapes a varié de 23 pour le meilleur animal à 277 épreuves pour le pire. La moyenne pour le groupe a été de 94 épreuves. Les corrélations de rang basées sur toutes les épreuves ont été peu élevées et inconstantes mais positives.

On a divisé 32 des chatons choisis au hasard parmi les mêmes animaux en trois groupes et on les a testés avec le même nombre de problèmes avancés pour déterminer les limites de l'apprentissage en séries de cette sorte générale. Ces problèmes se sont ressemblés parce que les complications se sont composées d'ajouter autant d'étapes additionnelles que possible mais ont été différents l'un de l'autre parce que le premier n'a exigé nul ordre spécifique, le deuxième a exigé un renversement de la direction à certains points critiques et le troisième a exigé une continuation de la direction à ces mêmes points. Le premier s'est montré le plus facile des trois parce que tous les chatons testés ont pu ajouter cinq étapes additionnelles, en comparaison d'une seule étape additionnelle dans le deuxième et nulle dans le troisième. On n'a trouvé nulle différence constante de sexe dans ces problèmes quoique trois sur les quatre meilleurs animaux aient été mâles. On a trouvé de grandes différences individuelles. Le meilleur animal en chaque cas a pu ajouter huit étapes dans le premier problème, cinq dans le deuxième, et sept dans le troisième. Le rang d'un chaton n'a été constant, ni dans un problème simple ou fondamentale ni dans le problème complexe qu'on lui a donné plus tard.

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DIE GRENZEN DER LERNKRAEFTEN BEI KÄTZCHEN

(Referat)

Es wurden 82 gewöhnliche Kätzchen, sowohl männliche wie weibliche, im Alter von 8 bis 9 Wochen, an der Aufgabekiste (problem box) von Jenkins geschult. Die Kiste bestand aus einem grossen Probekäfig (test cage), 135 cm. breit, der durch ein Drahtgitter von einem kleinen inneren Käfig abgeschlossen war, welcher den Reiz enthielt. Auf dem Boden des Käfigs lagen drei Platten, 15 cm. breit, von denen jede 1 cm. über den Boden erhoben und für Elektrisierung (shocking) mit Draht versehen war. Diese Platten waren in drei der Quadranten gleichmässig verteilt. Der vierte Quadrant enthielt die Türe der Probe-und Reizkäfige. Ehe die innere Tür freigelassen wurde, musste das Tier reagieren indem es eine oder mehrere der elektrischen Platten, je nach Bestimmung des Versuchsleiters, berühren musste. Durch drei Ablösungen (relays) konnte das Apparat so geregelt werden, dass das Oeffnen der inneren Türe nur durch eine komplizierte Gestaltung (pattern) der Reaktionen verursacht werden konnte. An allen Kätzchen wurden morgens und abends,—ungefähr jede zwölf Stunden,—5 Versuche gemacht. Sie wurden immer nur gleich nachdem sie gelaufen waren gefüttert. Als Reize dienten Stückchen rohen Fleisches und eine Schüssel Milch. Gelangen dem Kätzchen neun aus zehn Versuche, so hielt man, dass es der Aufgabe Meister war. Jeder Versuche durfte fünf Minuten dauern. Das Bestreben, die Aufgabe zu lösen, galt nur nach 100, oder, wenn die Tiere in ihren Bemühungen beharrten, nach 1200 bis 1500 Versuchen, als mislungen.

Nach Vorversuchen an einigen Tieren wurden 52 Kätzchen geprüft an einer einfachen oder grundlegenden Aufgabe bestehend aus einer Serie von drei Stufen bei denen eine spezifische Ordnung nötig war. Die Tiere mussten lernen: (1) Irgend eine besondere Platte zu betreten; (2) zwei besondere Platten zu betreten; und (3) alle drei Platten zu berühren. Allen Kätzchen war es möglich, die drei Stufen zu erlernen. Weibliche Kätzchen taten dies etwas besser als männliche. Es gab aber grosse Unterschiede zwischen individuen. Die Gesamtzahl der nötigen Versuche an den drei Stufen erstreckten sich von 23 bei dem tüchtigsten Tier bis zu 277 bei dem untüchtigsten. Die mittlere Zahl für die Gruppe war 94 Versuche. Korrelationen nach der Rangmethode (rank correlations), gegründet auf die Gesamtzahl der zum erlernen der drei Stufen nötigen Versuche, waren niedrig und unzuverlässig neigten aber in die positive Richtung.

Etwa 32 der Kätzchen, aufs geratewohl unter den obenerwähnten Tieren abgezogen, wurden in drei Gruppen eingeteilt und an schwereren Aufgaben erprobt, um die Grenzen stufenweisen Lernens dieser allgemeinen Art festzusetzen. Diese Aufgaben waren insofern einander gleich, dass die Verwicklungen (complications) darin bestanden, dass man so viele weitere Stufen wie möglich hinzufügte, warin aber darin verschieden, dass die erste keine besondere Anordnung in Anspruch nahm, die zweite an gewissen kritischen Stellen eine Umkehrung der Richtung und die dritte eine Fortsetzung der Richtung an diesen selben Stellen verlangte. Die erste Anordnung erwies sich als die leichteste der drei, da es allen Kätzchen möglich war, 5 weitere Stufen hinzuzufügen, wärend in der zweiten Aufgabe nur eine und in der dritten überhaupt keine hinzugefügt werden konnte. Es erwiesen sich bei diesen Aufgaben keine beharrlichen Geschlechtsunterschiede, obwohl 3 der 4 tüchtigsten Tiere männlichen Geschlechts waren. Es zeigten sich ausgeprägte individuelle Unterschiede. Dem tüchtigsten Tiere war es in jedem Falle möglich, in der ersten Aufgabe 8, in der zweiten 5, und in der dritten 7 Stufen hinzuzufügen. Es erwies sich keine Uebereinstimmung bei der Rangordnung eines bestimmten Kätzchens in Bezug auf eine einfache oder grundlegende Aufgabe im Vergleich mit einer komplizierten Aufgabe welche ihm später zugewiesen wurde.

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THE EFFECT OF HABIT INTERFERENCE UPON PERFORMANCE IN MAZE LEARNING*

From the College of Education of the University of Minnesota

By

OSCAR WILLIAM ALM

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CONTENTS

I

THE TREND OF PREVIOUS INVESTIGATIONS OF HABIT INTERFERENCE

This study had its beginning in the conviction that in any learning situation previous experience might constitute a handicap to improvement comparable with poor learning ability. This would be true especially if certain response patterns were so definitely connected with elements common to a variety of situations as to appear persistently and irrelevantly. The outcome would be conditioned inability, analogous, as far as the usual objective indications are concerned, to poor intelligence. The emphasis placed during recent years upon the possibilities for conditioned behavior and upon the importance of the early experiences of childhood gave further impetus to the investigation of such negating factors.

The problems of habit interference constitute no new field for investigation. Although the studies having a direct bearing upon this problem are few in number, they have contributed considerable data to a knowledge of the existence of habit interference, to a knowledge of the conditions under which it takes place, and to a knowledge of its effects upon behavior. The existence of habit interference in some form might well be accepted, as a review of previous studies will indicate. But the conditions under which interference has been observed should be considered. It appears in a number of studies that interfering habits are in some degree antagonistic responses made to similar or identical

stimuli. As early as 1892 Bergstrom (3) reported the results of several experiments in card sorting. The average time for sorting the second pack ranged from 3.5 seconds to 17.5 seconds longer than the average time for the first pack. Bergstrom concluded "that in spite of every effort, a very decided interference takes place when we attempt to associate a new reaction with an old stimulus." The same principle was set forth by Müller and Schumann (24) in 1894 as the law of associative inhibition. They said, "If *a* is already connected with *b*, then it is difficult to connect it with *k*; *b* gets in the way." Bair (1) found in his experiments with typing color series and letter series that the rise in the practice curve at the beginning of a new order was greater when the ***responses to a common stimulus*** were changed than when the *series order of stimuli* were changed. In Culler's (8) typewriting and card-sorting experiments the same conditions of similar stimuli and different responses were undoubtedly obtained. In the former, the practice materials were three-place numerals. The keyboard of the typewriter was concealed and only the middle row of keys was used. The keys were numbered from 1 to 9, beginning at the left, for the first habit. For the second habit the numbering of these keys was changed. In card sorting the sorting boxes were changed so that the placing movement for each card was very different in one habit from the movement required in the other. Both of these series of experiments resulted in some interference, as Culler concluded and as his data indicate. Kline and Owens (19) and also Brown (7) claim to have found

considerable evidence of habit interference in card-sorting experiments in which this same general stimulus-response condition very likely existed. In these earlier experiments the practice materials in every case probably presented the conditions of like stimuli but different or antagonistic responses.

In 1915 there were reported two investigations in which negative transfer was tested with a variety of practice materials, ranging from close similarity to marked dissimilarity. The first, Poffenberger's (26) study, indicates that canceling digits in number groups resulted in marked improvement in canceling number groups that included the same digits; whereas color naming interfered with form naming, giving opposites interfered with adjective-noun associations, and adding interfered with multiplication. Similar findings were obtained by Martin (21). The practice materials consisted of canceling words containing both *a* and *t* in English prose. The initial and final tests consisted of canceling Spanish words containing *a* and *t*, Spanish words containing *e* and *s*, *a* and *t* in series of small English letters, *e* and *s* in series of small English letters, groups of figures containing *4* and *7*, and *A* and *B* in series of capital letters. Clear evidence of negative transfer was found in the *e* and *s* letters test, the *e* and *s* Spanish word test, and the *4* and *7* number-group checking test. The importance of Poffenberger's and Martin's studies consists in the fact that, whereas their materials presented different stimulus-response conditions, negative improvement was found only in situations where the principle of like stimuli but antagonistic or different responses probably applied.

The same condition seems to be essential to habit interference in animals. This was probably established in rat studies reported by Hunter and Yarbrough, Pearce, Wylie, and Hunter. The habit of going to the right of a T-shaped discrimination box for hand claps and to the left for silence interfered greatly with learning to go to the right for silence and to the left for a buzzer (16). The interference of visual habits in rats was even more pronounced (25). Learn- to go to the right for light and to the left for darkness required from 60 to 300 trials. In the second habit, with reverse stimuli, only one animal learned the association. It required 420 trials. The rest of the group were given 680 to 1160 trials. These findings, under the conditions of similar stimuli and antagonistic responses, are in sharp contrast with Wylie's findings under the condition of different stimuli but like responses (38). Habits of avoiding one type of visual, auditory, or painful stimuli transferred positively in learning habits of avoiding a different type of stimuli. The savings ranged from 25 to nearly 75% of the average number of trials required in original learning. In four experiments with rats and one with humans, Hunter obtained results that confirm the same principle (15). Studies of visual habits in rats, similar to Pearce's study, gave evidence for negative transfer, as shown in Table 1.

TABLE 1

	Av. No. trials	*P.E.*
Habit 1	286	68.12
Habit 2	603	103.10
Difference	317	33.52

Likewise, with number of trials as the criterion, the simple maze habit of running to the left side of a T-shaped discrimination box for food interfered significantly with learning to run to the right side. However, in using a complex circular maze, the habit of running to the food entrance at the right side greatly facilitated learning to go to the food entrance at the left side. All criteria showed positive transfer. A complex stylus maze gave similar results for humans. These findings with complex mazes agree with the results from Webb's (35) maze studies of transfer in rats and humans. In the latter all important differences between control and experimental groups showed that learning a common complex maze, *A,* facilitated learning another complex maze, *B, C, D, E,* or *F,* and likewise learning any complex maze, *B, C, D, E,* or *F,* facilitated learning a common complex maze, *A.* Moreover, there was such close agreement between the findings for rats and humans at many points that Webb concluded that "human and animal organization is highly similar so far as the laws and conditions of transfer are concerned." These results from the study of interference in complex mazes should not be taken either as exceptions to the principle of like stimuli but antagonistic responses, or as evidence of no negative transfer.

Such results might have various probable causes. It is possible that the specific aspects of complex patterns do not transfer readily either positively or negatively. The control and experimental groups may not have been equated for general positive-transfer effects.

Webb's maze study of retroaction in rats and humans tends to support this position (35, p. 83). The pairs of mazes that gave no differences or only slight differences in favor of positive transfer produced marked retroactive disturbances in both rats and humans. The interference showed up in retroaction because the general positive-transfer effects were more nearly equated for the control and experimental animals. In the transfer experiments the negative transfer was offset by positive transfer. Finally, it seems very possible that, if a complex pattern transferred negatively and as a unit, it would be not only very uneconomical as compared with the right pattern for the second habit, but different in its stimuli as well. This might be especially true if "stimuli" in this connection includes kinaesthetic and near central cues.

Some light on the stimulus-response relationship necessary to interference between habits or mental functions has been contributed by studies on retroactive inhibition. In spite of the claims made by Müller and Pilzecker (23) and Heine (13) that the temporal position of interpolated work is the important factor, the most pronounced interference in such experiments has been found to depend upon the similarity between the interpolated work and the memorized materials.

In several experiments using materials dissimilar to interpolated work, DeCamp (11) found very little evidence of retroactive inhibition. He concluded that the interference found in other experiments was due to the similarity of the materials. The results from Robinson's (27) experiments indicated that the degree of

interference varied directly with the degree of similarity between interpolated work and the memorized materials. He concluded, "The greatest inhibition always was caused by the interpolation which apparently had the most elements in common with the original learning." Skaggs (31) reported several experiments similar to Robinson's, using very short time intervals between memorizing and interpolated work. Although his data tended to show that the temporal position of interpolated work is important, they also confirmed, in the main, Robinson's findings on the influence of similarity. He found that, whereas very similar or identical materials did not produce interference, beyond a certain point, the more dissimilar the materials the less the detrimental influence, but it never reached zero. These findings in retroactive inhibition studies point toward the probability that complex behavior patterns might not interfere to any considerable extent in transfer situations unless their processes, especially beginning processes, are similar. Probably neither marked similarity nor marked dissimilarity between behavior patterns is the condition conducive to the highest degree of interference. Complex patterns are likely to be too different or indefinite to produce appreciable amounts of interference.

Although, directly or indirectly, the data have contributed more toward the importance of the stimulus-response conditions in habit interference than toward any other factor, slight contributions have been made to several other factors. The degree of learning or automatism of interfering habits or functions is very

likely a factor. In card-sorting experiments Culler found that in the alternate practice of two sorting arrangements "the difference in time between one sorting and another requiring antagonistic reactions is greater the greater the number of successive sortings of the first arrangement (8, p. 50). Kline (19) found that the stronger the associations between states and their true capitals, and between literary works and their true authors, the less they interfered with learning associations between states and false capitals and literary works and false authors. The mode of memorizing which he used, however, may have resulted not only in associating the false elements with certain states or literary works but in associating them with the true elements as well where the latter were well known. That meant that the interfering associations were probably not *a-b* and *a-c* associations, but *a-b* and *a-b-c* associations. From retroactive inhibition experiments Robinson and Heron's (29) data indicated that in memorizing series of nonsense syllables ranging from six to eighteen in length there was both absolutely and relatively less inhibition with increasing length of materials. They concluded that the "more rapid forgetting of shorter materials is probably a function of the lack of practice in this type of memorizing." In a study of mental set and shift Jersild (17) obtained different results. Uniform series of such mental operations as addition and multiplication, word naming and form naming, form naming and substitutions, calculation and controlled association, etc., were first performed separately and then alternately by alternating

individual items from the two separate tasks. The results indicated that the more highly the separate uniform activities were automatized the greater the loss from shift in the combined performance. The degree of learning as a factor in interference needs further investigation.

Of the various factors in habit interference none should be more interesting than age. But little has been done to determine its influence. Thorndike (73, pp. 84-89, 262-265) had 54 graduate students transcribe series of disconnected words by substituting *g* for *a*, *t* for *b*, *y* for *c*, and so on. Then they reversed the code substituting *a* for *g*, *b* for *t*, and *c* for *y*, etc. Later a similar new code was practiced. He found the "more negative the transfer the more the older men lose by the change." This study is very suggestive in view of McGinnis' (22) study of interference in preschool children. The group averages in learning stylus-maze patterns which were planned to produce interference showed only positive transfer. That interference may be present in the learning of older children has been demonstrated by Martin (21, pp. 16-50). His subjects were largely school children.

The studies of habit interference have not in the main contributed much concerning the effects of interference upon performance except increase in time, increase in number of trials, or increase in frequency of errors. Culler (8, pp. 17-19) noted in the results from his typewriting experiments that the best index of the interference of old associations was in their recurrence. These relapses ranged from 3-66 per subject during the

fifty repetitions of the second habit. Kline and Owens (19, p. 244) claimed that many errors of the second series in card sorting were correct distributions of the first and that such errors were most likely to occur when the speed was forced beyond the power of the delivering habit. These two studies point directly toward the negative transfer of response patterns, or elements, as the interference. Book (5), in his study of the acquisition of skill in typewriting, investigated the causes of plateaus. His subjects observed introspectively that "the older more elemental habits used in earlier stages of writing tended to persist and force themselves upon the learners long after they had been superseded by higher order habits." The best evidence of plateaus, or really of marked retardation, in learning was found by Hunter and Yarbrough (16, p. 65) in the interference of auditory habits in rats, and by Pearce (25, pp. 175-177), and later by Hunter (15, p. 36) in the interference of visual habits in rats. Culler concluded that in the alternate practice of two different orders of card sorting the interference was often overcome in a few seconds, there were no plateaus, and no interference effect was retained from one day to the next (8, pp. 79-80). But a comparison between the control groups and the alternate-practice groups, having approximately the same initial sorting ability, shows much lower average time scores for the controls than for the alternate-practice groups in all of the later levels of practice for both men and women. The interference effect must have persisted. On the other hand, the data from Bergstrom's experiment in

TABLE 2

MEAN DIFFERENCE IN SECONDS FOR EACH PAIR OF SORTINGS

	Time intervals between sortings						
	3″	15″	30″	60″	120″	240″	480″
Average	25.54	21.07	18.61	15.98	13.62	12.98	11.25

sorting picture cards shows that interference may under certain conditions depreciate rapidly with time (3, p. 364). The time interval between sortings was varied. Table 2 shows the average difference in time, or increase in time, for the second sorting arrangement, for 70 comparisons for each time interval. In this connection, it should also be noted that some subjects seem to be immune to interference, at least in certain functions or habits. This has been noted by Culler (8, pp. 17-22) in his typewriting experiments and by Brown (7, pp. 303-306) in card sorting.

The possible immunity of some subjects and the marked persistence of interference in some cases may account for the presence of increased variability under conditions of interference. This was observed by Culler in his typewriting experiments. He concluded, "The negative correlation between the relapses and the rate of improvement shows that individual differences in adaptability to a new situation in the face of persisting old associations are greater than under the conditions of ordinary practice" (8, pp. 22-23). Hunter's data on interference indicates greater variability in the second than in the first habit in visual habits, but less variability in the second habit than in the first in maze habits. Does this mean greater variability under conditions of interference and lower variability under

conditions of positive transfer? That should be determined by further experimentation.

Summary

The trend of the findings in the studies of interference points quite conclusively to two things. (1) Habit interference is likely to appear in certain learning situations in both humans and animals. (2) Interference is most pronounced and most likely to appear between situations with like stimuli but opposite, different, or partly antagonistic responses. There are some scattered data tending to show, or suggest, (*a*) that the interference consists of relapses to the correct responses of the first or interfering habit, (*b*) that the degree of learning is a possible factor in the amount of persistence of interference, (*c*) some subjects seem to be immune to interference, (*d*) that in learning difficult habits interference may be an important cause of plateaus, (*e*) that interference is more noticeable in older subjects than in younger subjects, (*f*) that interference increases variability, (*g*) that habit interference does not develop in learning complex mazes and is not very evident in learning simple mazes, (*h*) that "human and animal organization is highly similar so far as the laws and conditions of transfer are concerned."

Problem

In view of these trends in the studies of interference it seemed most worth while to investigate the following theses:

1. Interference in transfer situations consists largely

of the transfer of response patterns from the first, or interfering, habit.

2. In certain situations plateaus in learning are due to the persistence of relapses to response patterns previously acquired.

3. Response patterns, or response elements, acquired in any learning situation may have both positive and negative effects in such proportion that no significant differences appear in total time, distance, or error scores.

4. Negative transfer may be present in maze learning and influence improvement in a significant way.

The investigation was carried on in such a manner that the data might throw some light on the following problems:

1. The persistence of interference in terms of recurrence in retention tests and in resistance to reconditioning.

2. The relation of interference to age.

3. The relation of interference to automatism.

4. The effect of interference upon variability.

II

APPARATUS, SUBJECTS, AND PROCEDURE

This investigation began in November, 1926, and the experimentation continued until July, 1928. All the experiments were performed in a special laboratory at the University of Minnesota. The method adopted was that of control groups. The experiments were limited to negative transfer situations. For the most part, the variation of experiments consisted of differences in the age of the subjects and in the conditions of learning. The subjects were 356 pure strain Wistar white, or albino, rats. The learning consisted of easy and difficult maze habits.

Apparatus

In view of the nature of the problem for investigation, the apparatus used had to meet certain requirements. (1) The pairs of mazes should provide the condition of like stimuli but antagonistic responses. (2) The first maze learned should be so easy that (*a*) all animals would complete learning before being transferred to the second maze, and (*b*) no marked differences in amount of maze practice, or in the age of the animals at the end of complete learning, would appear. (3) The second maze had to be of such complexity and difficulty that different response patterns would appear sufficiently frequently to be observed and statistically treated. It was necessary, moreover, that graphic records be made of every performance of each animal.

There were certain other requirements that were not

so urgent, and some needs for improvement over the usual maze construction which, it seemed, should be met. (1) The mazes should be simple in order that large numbers of animals could be used without exorbitant demands on time in beginning trials. (2) The ends of the maze alleys should not be visible to the animal. (3) All blind alleys should be the same length. (4) The approaches to crucial points in the maze should be limited spatially in such a manner as to present to the animal, from trial to trial, similar angles for turning and similar openings to alleys. (5) All alleys should be graduated in distance so that the total distance of any run might be determined accurately. (6) Errors should be scored in terms of distance and not in an all-or-none fashion. (7) There should be pairs of mazes of similar difficulty.[1]

The attempt to meet the foregoing requirements and needs for improvement resulted in the construction of the cluster of mazes shown in Figures 1 and 2. Only one problem box was used. Figure 1 shows the box adjusted for the mazes with alleys open to the right side and Figure 2 shows the box adjusted for the mazes with alleys open to the left side. The number for each maze, the entrance, the true paths, the blind alleys, the alleys closed, and the location of the food box are shown in Table 3. Mazes 1, 1*a*, 3, 3*a* are shown in Figure 1, and Mazes 4, 4*a*, 2 and 2*a* are shown in Figure 2. The problem box might be readily adjusted to form other mazes, but these were the only ones used.

[1]Since the beginning of this investigation some of the improvements noted here have been attained in the construction of the Multiple-T maze. See (81).

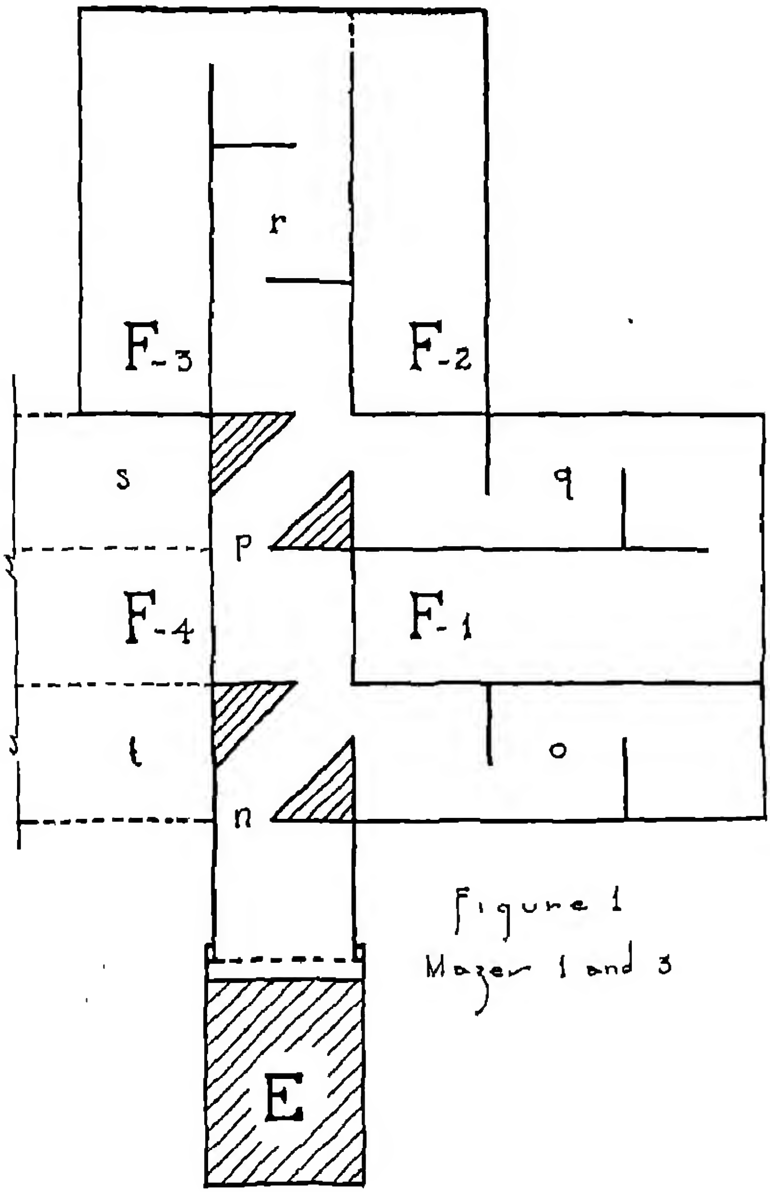


Figure 1
Mazes 1 and 3

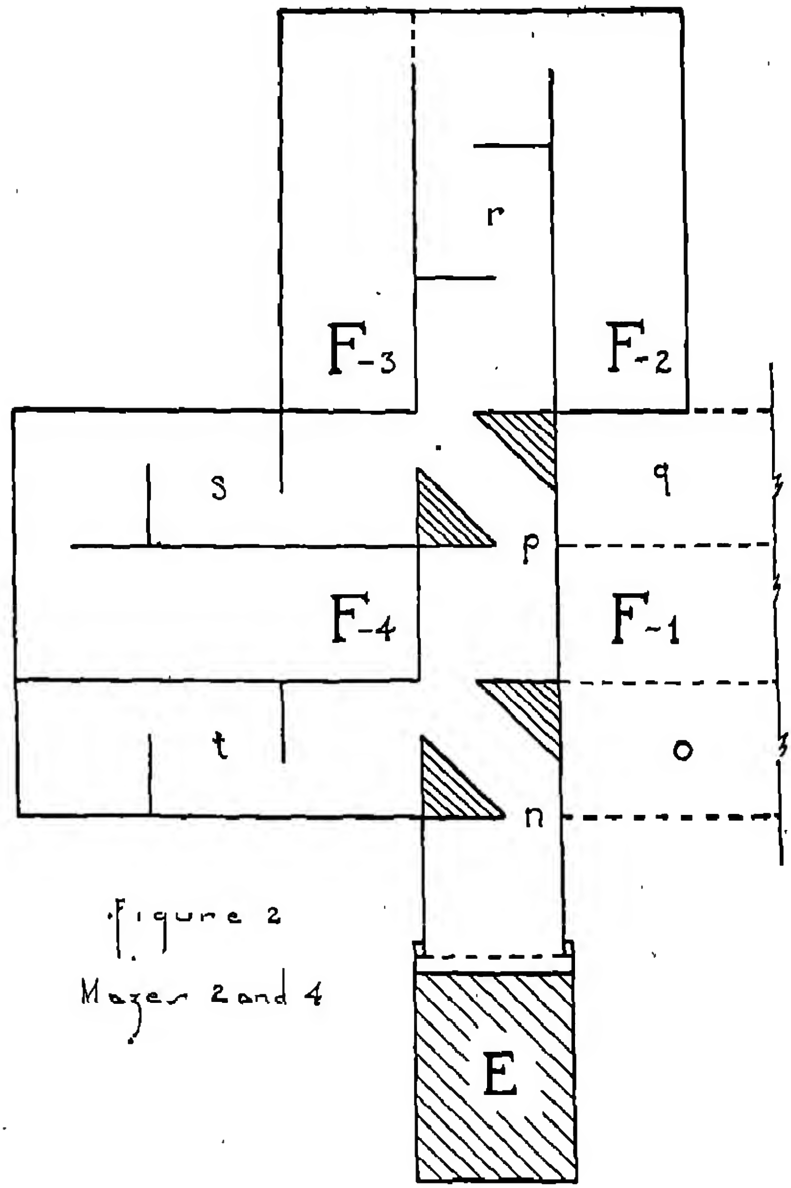


Figure 2
Mazes 2 and 4

TABLE 3
MAZES

Mazes*	Entrance	True paths†	Blind alleys	Food box
1	E	*n-p-q*	*o r*	1
1*a*	E	*n-p-q*	*r* (*o* closed)	1
3	E	*n-p-r*	*o q*	3
3*a*	E	*n-p-r*	*q* (*o* closed)	3
4	E	*n-p-s*	*t r*	4
4*a*	E	*n-p-s*	*r* (*t* closed)	4
2	E	*n-p-r*	*t s*	2
2*a*	E	*n-p-r*	*s* (*t* closed)	2

*Mazes 1, 1*a*, 3, and 3*a* are shown in Figure 1, and Mazes 4, 4*a*, 2, and 2*a* are shown in Figure 2.
†See Figure 9 for true paths.

The change from right-side mazes to left-side mazes was accomplished by changing the movable triangular blocks in the main alley and the partial obstructions in alley *r*. Mazes 1 and 4, 1*a* and 4*a*, 3 and 2, and 3*a* and 2*a* were geometrical opposites of similar pattern and probably of similar difficulty.[2]

The problem box was made of soft pine and painted a dull black. The main alley, *n* and *p*, was 20 inches long, 5 inches wide, and 8 inches deep. All other alleys were 15 inches long, 5 inches wide, and 8 inches deep. The partial obstructions were placed 5 inches apart from center to center and thus formed the maze units for distance scoring. The openings left by the partial obstructions were 2⅛ inches wide. The approaches to the entrances of the alleys were 2¾ inches wide. The entrances to the food boxes were opened and closed by sliding doors regulated by levers. The whole maze was covered with metal-wire-cloth.

The data obtained consisted of trials, time scores,

[2]See Figure 9 for true paths.

distance scores, and a graphic record of each run. Time was taken in fifths of a second by a stop-watch. The distance for each run was computed from the graphic records. The apparatus for taking these records consisted of a mirror 20" x 30", six electric light bulbs of low voltage, and a stylus maze of the same pattern as the animal maze. The mirror was hung directly above the maze at such an angle that the observer seated at the table on which the maze was placed had a clear view of the rat's performance without being seen by the animal.[8] The electric light bulbs were all attached to the frame of the mirror in such locations as to illuminate all the maze alleys. The stylus maze for record taking was made of heavy sheet aluminum. Over all, the size was 8" x 11" and the alleys were 1¼ inches wide. It was hinged to a clip board which contained the paper on which the record was made. In any trial, as the rat moved through the various alleys, the observer took the same route in the stylus maze, drawing the pattern on the paper below.

ANIMALS

All the animals used for this investigation were pure-bred Wistar white rats. They were all of the same stock and highly inbred. No commercial rats were used. All animals were reared in the laboratory and cared for by the writer exclusively. They were tame

[8]In view of the angle of reflection, the obstructions in the maze, the wire cloth covering of the maze and the glare of light above the animal any view which the animals might have had of the observer's head- and arm-movements from the mirror must have been slight at most. There was no evidence whatever of the animals being disturbed in that way.

and great care was taken to prevent any fear reactions from developing. They were caged in groups of 4 to 7. The cages were made of large-mesh wire-cloth with floor spaces of 12" x 17" or 18" x 19" which provided amply for activity. Very liberal allowances of sawdust were used for bedding and all cages were cleaned regularly. In the case of experimental animals, males and females were segregated before 40 days of age.

All animals were fed regularly once a day. The diet for experimental and control animals was composed of white bread, skim-milk or whole milk, cod liver oil, and scraps of green cabbage, lettuce, or spinach. Non-experimental animals were fed a commercial poultry growing-mash.[4] All experimental and control animals except very young rats were placed on the experimental diet at least one week before beginning maze running.[5] All animals in experimentation were fed the same hour every day. Variations from this order in feeding and grouping will be noted in connection with the discussion of the experiments.

Procedure

The distribution of practice was one trial a day for learning and relearning for all animals except very young rats. Animals beginning learning at 20 days of age, and all control animals for such groups, were given two trials a day throughout training, one trial in the

[4]This mash, through earlier comparison of growth records against Wistar norms, seemed to constitute a very adequate diet.

[5]Very young rats were weaned at 18 days of age and were placed in training at 20 days of age. They were on the experimental diet only two days before the beginning of the learning.

morning before ten o'clock and one trial in the evening after seven o'clock.[9] The trials were given at the same hour every day, seven days a week. The criterion of complete learning and also of relearning the first maze habit was three consecutive errorless trials, unless otherwise indicated. The criterion for complete learning and relearning the second maze habit was six consecutive perfect trials. A perfect, or errorless trial, was defined to include no entrance into blind alleys, no retracing, and no exploratory reactions such as sitting erect. Hesitations at the entrance to blind alleys were not counted as errors.

The steps most common to all the experiments in the training procedure for experimental animals were as follows:

A. For transfer from easy to difficult learning:
   1. Complete learning of Maze 2 (or Maze 3)
   2. Rest three days
   3. Complete relearning of Maze 2 (or Maze 3)
   4. Rest three days
   5. Forty trials in Maze 4 (or Maze 1 if Maze 3 was the first one learned)

B. For transfer from easy to easy learning:
   1. Complete learning of Maze 2*a* (or Maze 3*a*)
   2. Rest three days
   3. Complete relearning of Maze 2*a* (or 3*a*)
   4. Rest three days
   5. Complete learning of Maze 4*a* (or Maze 1*a* if 3*a* was the first maze learned)
   6. Rest six days
   7. Relearning Maze 4*a* (or 1*a*)

Easy mazes were selected for the first habits for reasons

[9]Early weaning of very young rats necessitated feeding more than once a day. It seemed desirable not to feed the animals without running them. The attempt, moreover, was to develop the interference habit at the earliest stage of development possible.

which have already been stated.[7] The first rest period was given in preparation for the retention test, the relearning of the first habit.

Relearning was given to test the degree of completeness of first learning and to make it still more complete for all animals. The second rest was given to eliminate the more pronounced effects of immediate memory. The relearning of Maze 4*a* or Maze 1*a* in easy to similarly easy learning was done to test the possible recurrence of interference. The procedure for the control animals did not include the first four steps in either procedure for experimental animals. Moreover, *no preliminary maze experience* was given to the control animals before beginning the control learning. This was omitted to prevent any transfer from such experience.

Reliability

In determining the reliability and consistency of the performance and measurements three different methods were employed. (*a*) The self-correlations of distance scores were determined in order to measure the consistency of performance from day to day and from one stage of learning to another. (*b*) The correlations between geometrically opposite mazes of similar pattern were calculated in order to test the reliability of the mazes. (*c*) The correlations between time and distance scores were determined as a measure of the constancy of food incentive and external conditions of

[7]By easy mazes are meant mazes that were learned in six to ten trials on the average, as determined in the preliminary experiments.

learning. All correlations are Pearson r correlations determined with the use of the Otis Correlation Chart.

In determining self-correlations two methods were employed. (*a*) The total distance for the odd trials from 5 to 40 was correlated with the total distance for the even trials, from 5 to 40. (*b*) The total distance scores for Trials 9-24 were correlated with the total distance scores for Trials 25-40. These two methods were used for both control and experimental groups. The self-correlations obtained are shown in Table 4. The correlations between odd and even trials are rather high and almost the same for all groups and ages. No age differences appear in the correlations by either method. The correlations between different stages of learning are, on the whole, low. This is especially true of the correlations for control groups. Whether the differences between the control groups and experimental groups are due to differences in variability, or to retarded learning in the experimental animals, or to the persistence of a common factor, interference, in the experimental animals, is not indicated in the correlation data.

The second method of determining reliability was limited to one test for Mazes 1 and 4. Twenty-eight male rats, ranging in age from 57 days to 79 days at beginning training, were used. They were given the following training:

1. Complete learning of Maze 2
2. Three days rest
3. Forty trials in Maze 4
4. Six days rest
5. Complete learning of Maze 3
6. Three days rest
7. Forty trials in Maze 1

TABLE 4

SELF-CORRELATIONS ON DISTANCE SCORES ON MAZES 1 AND 4

Animals			Odd vs. even Trials 5-40			Trials 9-24 vs. Trials 25-40		
N	Approx. age*	Maze	Raw *r*	*P.E.*	S-B correc.‡	Raw *r*	*P.E.*	S-B correc.
52†	90	4	0.85	±.026	0.92	0.61	±.058	0.76
16	75	4	0.94	±.020	0.97	0.49	±.128	0.65
49	69	1	0.87	±.023	0.93	0.77	±.039	0.87
41	69	1	0.87	±.026	0.93	0.46	±.080	0.64
32	30	1	0.87	±.030	0.93	0.56	±.081	0.72
56	30	1	0.93	±.012	0.96	0.41	±.074	0.58

*The ages given are approximate average ages for the time of beginning learning in the maze indicated. The groups are composite groups of similar age and training.

†The boldfaced groups were experimental animals. Those not boldfaced were control animals.

‡Spearman-Brown correction.

The method was that of interpolating interference between practice in Maze 4 and practice in Maze 1. Learning Maze 2 had interfered with learning Maze 4. Consequently, complete learning of Maze 3 was given to offset the positive transfer from Maze 4 to Maze 1. This result was attained to a considerable extent as the data presented in Chapter III indicate. The correlations obtained by this method are shown in Table 5. These correlations are between the total scores for Trials 5-40 in Maze 4 and Trials 5-32 in Maze 1. A

TABLE 5

CORRELATIONS BETWEEN TOTAL SCORES ON MAZE 4 VS. MAZE 1

Animals		Data correlated		Correlation	
Age	*N*	Maze 4	Maze 1	Raw *r*	*P.E.*
77	28	Total distance Trials 5-40	Total distance Trials 5-32	0.52	0.092
	27*	Total time Trials 5-40	Total time Trials 5-32	0.57	0.087

*One animal was excluded because of very high time scores during convalescence from pneumonia. Distance scores were only slightly affected.

comparison of the mean total scores for different divisions of trials in learning the two mazes indicated that the stages of learning covered by Trials 5-40 in Maze 4 were similar to those covered by Trials 5-32 in Maze 1. The correlations obtained would have been much higher except for the marked inconsistency of one or two animals. It seems probable that a much larger number of subjects would have increased these correlations materially. They do indicate some reliability, but it may not be adequate for measuring individual differences.

The correlations obtained by the third method for Mazes 1 and 4 are shown in Table 6. The total time

TABLE 6

RELATIONSHIP BETWEEN TIME AND DISTANCE IN MAZES 1 AND 4 FOR TRIALS 5-40

Series	Animals		Pearson r	
	N	Age	Raw r	$P.E.$
A & B	51	90	0.758	0.0398
C	16	75	0.667	0.0929
D & N	49	69	0.827	0.0302
E & O	41	69	0.820	0.0342
F	32	33	0.794	0.0437
G & H	56	33	0.788	0.0339

scores for Trials 5-40 were correlated with the total distance scores for the same division of trials. These correlations are probably evidence of a rather high degree of constancy of the animals' food incentive and of the external conditions of learning. The individual differences in speed of the animals possibly account for the coefficients not being higher.

In the several tests of reliability there is no evidence of relationship between the degree of reliability, or con-

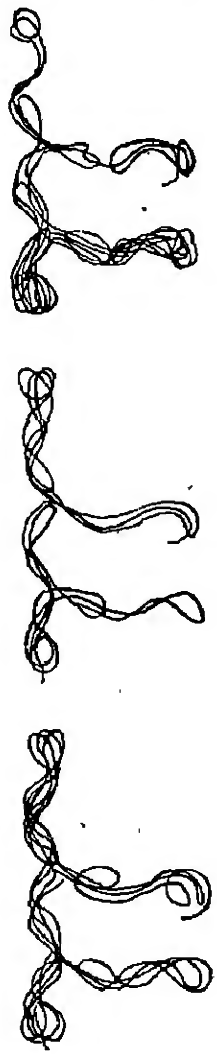
sistency, and the age of the subjects. The coefficients indicate consistently higher correlations between different stages of learning for experimental animals than for control animals. There were no other apparent differences in reliability correlations between the experimental and control animals.

Response Patterns

Graphic records of each performance made possible an analysis and classification of responses. The term *response pattern* is used in this study to mean one of the usual routes which the animals took in going to the food box. Mazes 1 and 4 were sufficiently complex to provide several different combinations of blind alleys and true alleys. They were also sufficiently simple that these routes to the food box, or combinations of alleys, were limited in number and might be clearly distinguished.

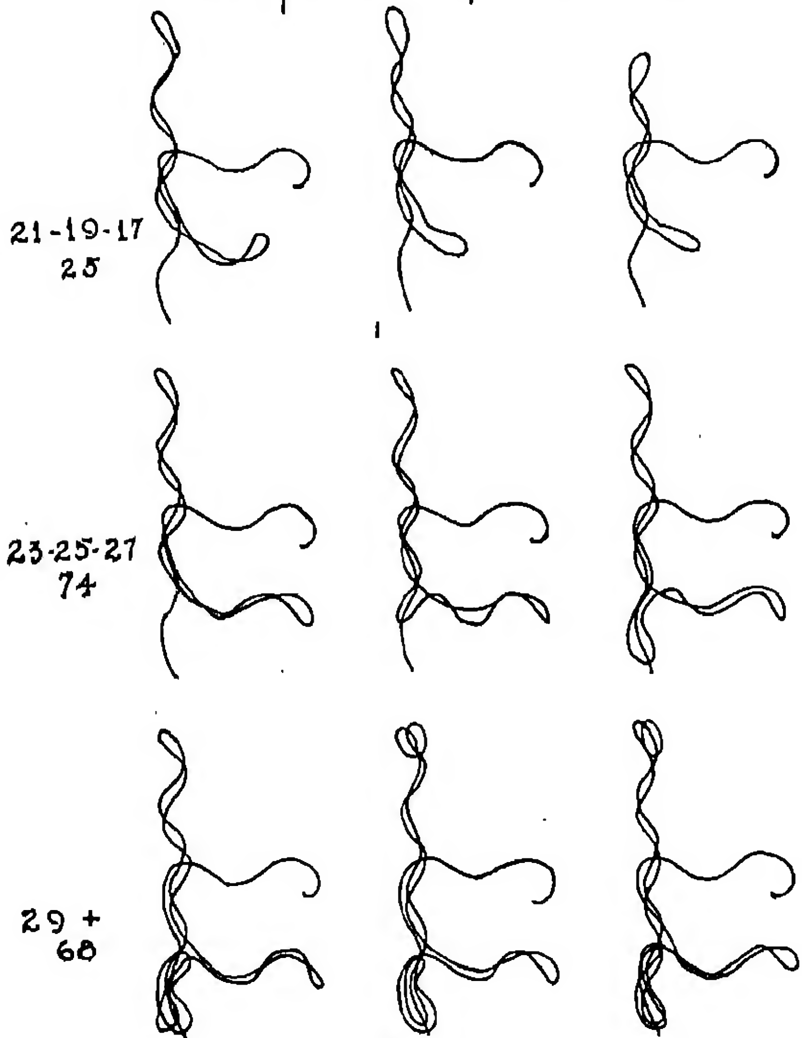
The analysis of performance revealed six different forms of responses. These forms and their principal variations are shown in Figures 3-8. In these figures the variations in form of each response pattern are grouped according to the distance scores they represent. At the left of each of these groups are two numbers. The upper one is the distance score and the lower one is the frequency of such forms in the total sample. The total sample in each case is shown as *n* below each figure. Figure 3 shows, in a general way, the response very common to beginning learning. It is obviously not a response pattern, but for convenience it will be referred to in this study as such and indicated by the letter *f*. Response *f* has no pattern; every *f*-response

Figure 3
Response Pattern -f-



M - 51
N - 196

Figure 4
Response Pattern b



N = 167

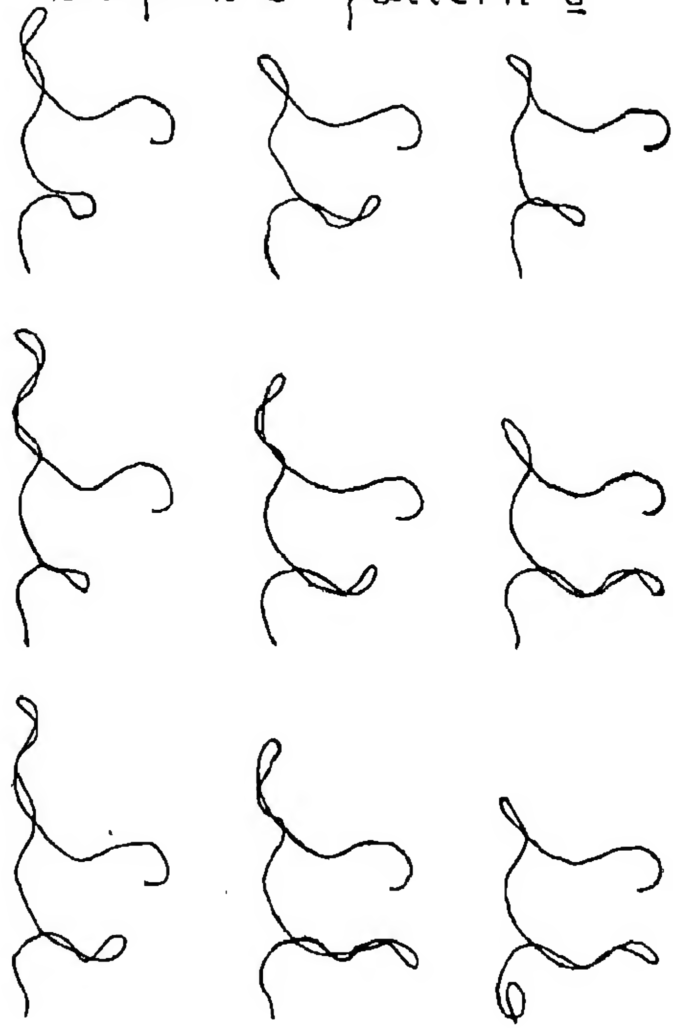
Figure 5

Response Pattern a

13-13-11
7

15
20

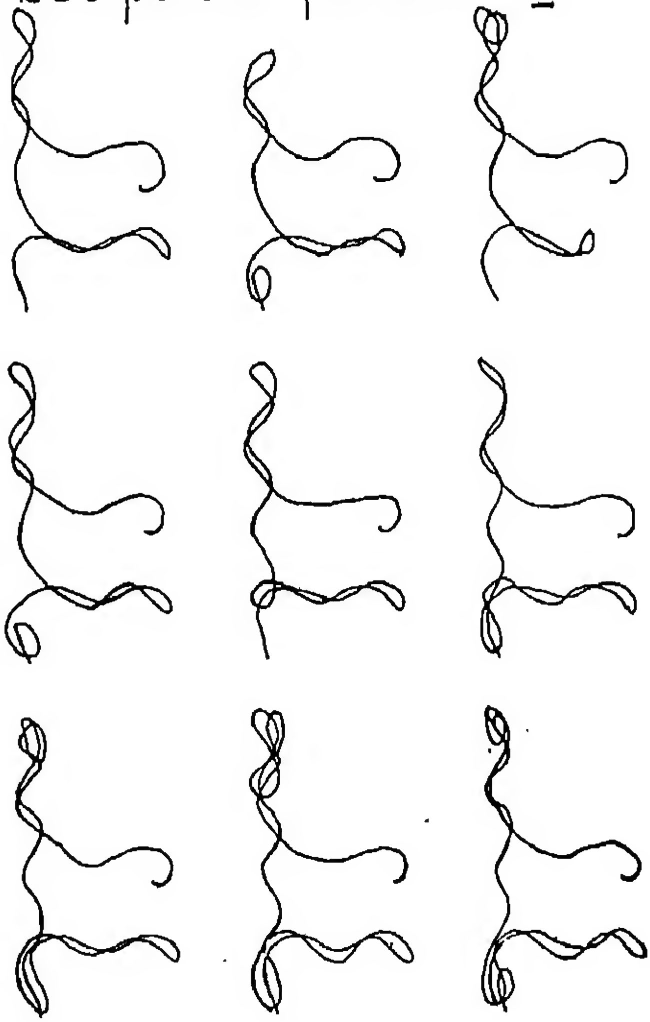
17
63



N = 423

Figure 5 (cont.)

Response Pattern e



19—
183

21-21·23
68

25 +
82

N = 423

is probably a variation in form from every other *f*-response. These responses are characterized by random movement, much retracing, and the absence of pattern. A sample of 196 *f*-responses, which is more than half of all the *f*-responses made by all animals in the several experiments with Mazes 1 and 4, gave a median distance score of 51 maze units.[8]

In Figure 4 are shown some variations of another form of response which will be referred to as response pattern *b*. It resembles *f* in some respects. It shows a large amount of retracing and exploration. But there was some uniformity of the *b*-responses from different animals and in a few instances this response pattern became a definite persistent habit. A sample of 167 *b*-responses, taken as the sample of *f*-responses was obtained, gave a median distance score of 28.5. Since the modal forms of this response have distance scores of 23, 25, and 27, it is clear that there was a considerable tendency toward uniform response patterns. Both *b*- and *f*-response patterns were so infrequent as compared with other patterns, as data presented in Chapter III and following chapters will show, that no problem was introduced by their lack of uniformity. They were very infrequent after the first four trials. The response pattern *e* and its principal variations are shown in Figure 5. It differed clearly from *b* and *f*

[8]The sample of *f*-responses consisted of all the *f*-responses by every fifth animal in the regular numerical list of the animals constituting each experimental and control series for all experiments with Mazes 1 and 4. To these were added all other *f*-responses made by 84 very young rats which began learning in Maze 1 at approximately 33 days of age.

TABLE 7
THE FREQUENCY OF EACH RESPONSE-PATTERN FOR DIFFERENT DISTANCE SCORES
A RANDOM SAMPLE

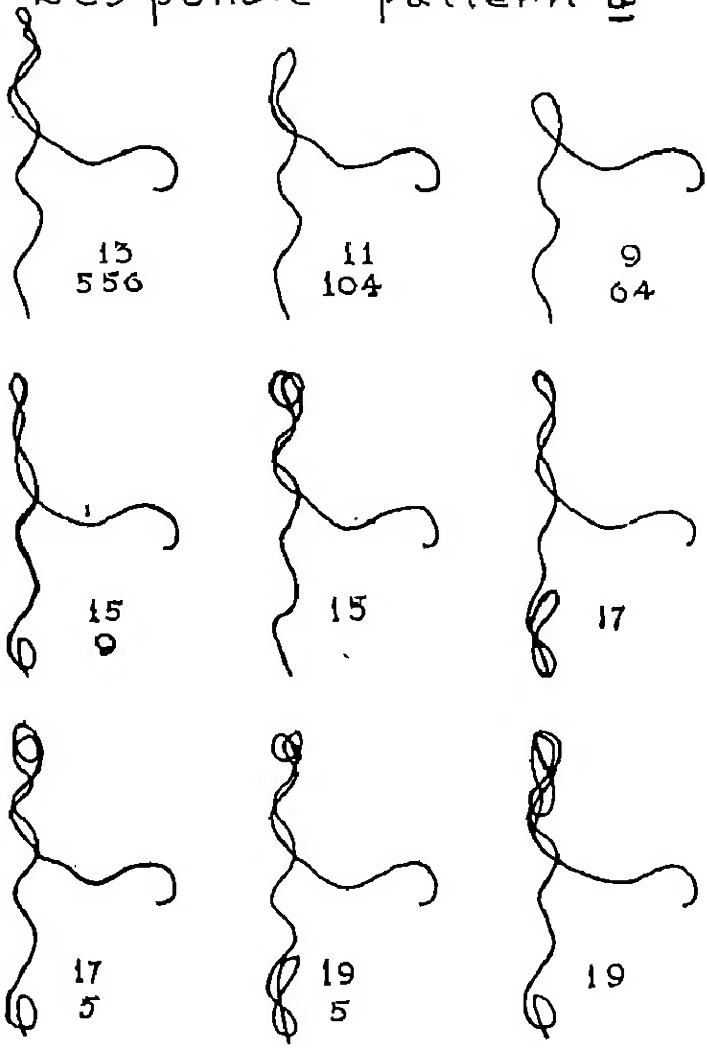
Response pattern	Distance scores 7	9	11	13	15	17	19	N
a		64	104	556	9	5	5	743
d		32	184	420	9	13	7	665
p	629	9	1	1				640

in several respects. The pattern itself is obviously different. It was more economical and much more uniform. A random sample of 423 *e*-responses which is approximately one-fifth of all *e*-responses made by all animals in all the experiments with Mazes 1 and 4 gave a median distance score of nineteen.[9] Of the sample, 273 responses had distance scores of 19 or less. This means that in approximately two-thirds of the *e*-responses there was complete uniformity in pattern. Response pattern *e* was much more frequent than *b* or *f*. It often became a habit in which some animals persisted over several successive trials, and to which other animals reverted from time to time all through learning.

The larger percentage of all responses, as data to be presented will show, consisted of *a*-, *d*-, and *p*-response-patterns which are shown in Figures 6-8. A random sample of these three response patterns, taken in the same manner as in the case of response *e*, is presented

[9]This random sample was obtained by taking all *e*-responses in every fifth trial by all experimental and control animals in all experiments using Mazes 1 and 4. The beginning point in the selection of trials was changed with each change in series of animals, so that all 40 trials might be represented in the total sample.

Figure 6
Response Pattern a



N = 743

Figure 7
Response Pattern d

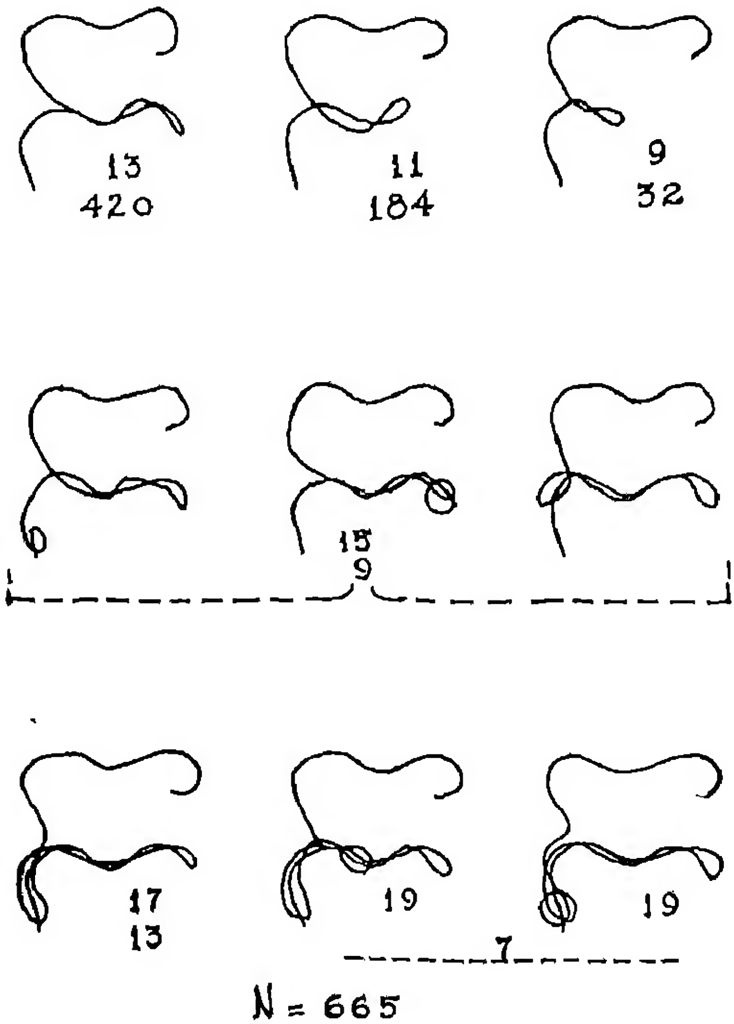
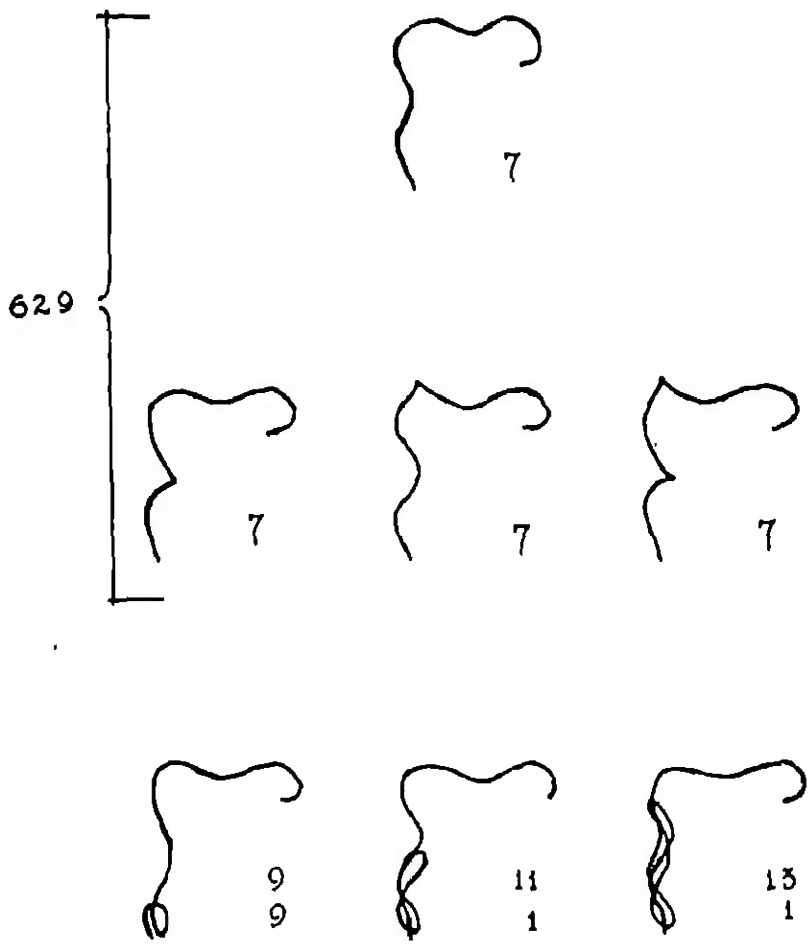
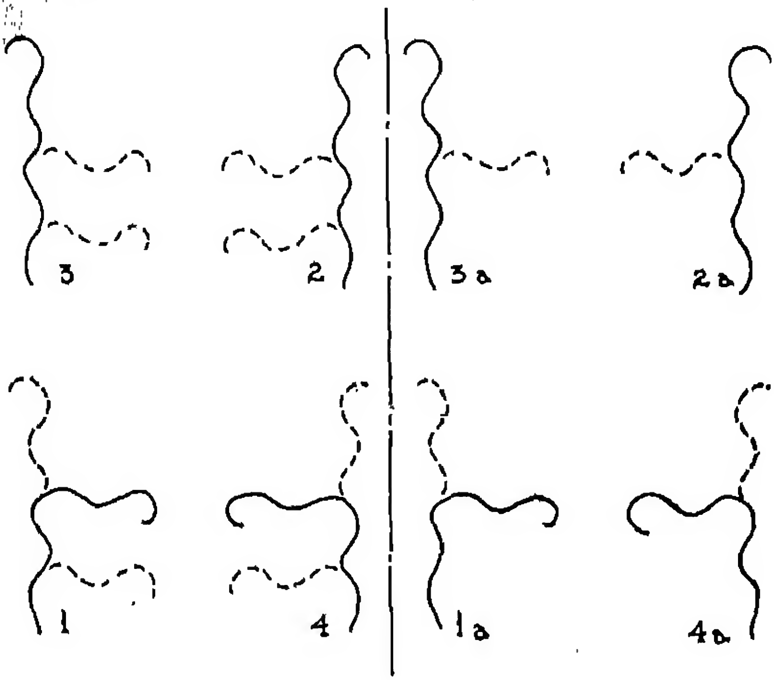


Figure 8
Response Pattern p



N = 640

Figure 9
Perfect Runs for Different Mazes



in Table 7. It shows the frequency of each for the different distance scores. If the variations of each of these response patterns are compared with the frequency of the distance scores which they represent, it will be seen that the number of responses with retracing was limited to 11 for response pattern *p*, 19 for pattern *a*, and 29 for *d*. The figures show what these deviations were. Figures 6-8 and Table 7 also show that the animals tended somewhat to run only two-thirds or one-third of each of the various blind alleys.

The frequency of *a*- and *d*-responses with distance scores of 9 and 11 is the evidence for this. Response patterns *a, d,* and *p* were clearly different in form. In the main, they were free from retracing and other exploratory reactions. They were uniform response patterns. In terms of the alleys run, and the order of running those alleys, response patterns *a, d,* and *p* (and to some extent *e*) are clearly indicated.

SUMMARY

1. The subjects in this study were 356 white rats of different age levels.
2. The procedure was a negative transfer procedure.
3. The method was that of control groups.
4. The practice material in all experiments was the complete learning of an easy maze.
5. The test material consisted of 40 trials in a difficult maze or complete learning of an easy maze.
6. The mazes were paired on the basis of similar, or identical, stimuli, but different, or largely antagonistic, true paths to food. By stimuli are meant the sensory cues, or signs, which the maze alleys presented.
7. The reliability of the difficult Mazes 1 and 4 is probably adequate for determining group differences. The coefficients of correlation between Mazes 1 and 4, which are geometrical opposites of similar pattern and probably of similar difficulty, for a series of 28 male rats was .522 for distance and .572 for time. The correlations between the total distance scores for odd and even trials for six groups of animals were uniformly high. The correlations between total distance scores and total time scores for six groups of animals were all

.76 or above. There is no indication that age affects the stability of performance. The correlations, however, between two different stages of learning were uniformly higher for experimental animals than for control animals.

8. An analysis of the performances in Mazes 1 and 4 revealed six different forms of response. One of these, response *f*, was entirely without uniform pattern. One other uneconomical exploratory response, designated *b*, showed some uniformity in pattern and in a few instances persisted as a definite habit. The *e*-responses were largely uniform in pattern and clearly different in form from any other pattern. There were three response patterns, referred to as *a*, *d*, and *p*, which were clearly different in form, free, in the main, from retracing and other exploratory reactions, and, with few exceptions, uniform in pattern.

III

COUNTERACTING POSITIVE TRANSFER BETWEEN SIMILAR MAZES

The aims peculiar to the experiments presented in this chapter were (*a*) to counteract positive transfer between geometrically opposite mazes of similar pattern so that reliability might be tested, and (*b*) to determine the degree of interference between such mazes when the general practice effects from maze experience were equated for the experimental and control animals. It seemed possible that habit interference, or negative transfer, might counteract the positive transfer between similar mazes to such a degree that a fair test of reliability might be made. The fact, moreover, that Webb (35) obtained negative correlations between the degree of "negative retroaction" and the degree of positive transfer for the several mazes he used gave the experimenter a strong conviction that if the experimental groups and control groups were equated for the general practice effects from maze experience, negative transfer might stand out significantly.

Preliminary Experiments

Experiment I

Procedure. For the first attempt to control, or offset, positive transfer Mazes 3 and 2 were selected. In learning Maze 3 the animal had to learn not to enter the two blind alleys to the right side, that is, not to make any right turns. It seemed possible that the

habit of taking only left turns and avoiding all right turns in Maze 3 would transfer to Maze 2 as a tendency to enter the blind alleys to the left side. For this experiment, Series A, 24 male rats, aged 70 to 81 days, were used. Their feed consisted of white bread soaked in skim-milk with cod liver oil, fed once a day, with scraps of green vegetables once a week.[10] The animals were fed all they would eat in eight minutes. The same food was used in the maze and each animal had approximately one-half minute to eat in the food box. Fourteen days after learning Maze 3 the animals were transferred to Maze 2.

Results. The results from this experiment were somewhat surprising. The mean scores for total distance, total time, and trials are shown in Table 8. The positive transfer effects in learning Maze 2 were even

TABLE 8
MEAN TOTAL SCORES AND STANDARD DEVIATIONS
SERIES A

	Distance		Time		Trials	
Maze	*M*	*S.D.*	*M*	*S.D.*	*M*	*S.D.*
3	69.87	27.68	130.70	63.60	6.76	1.87
2	35.00	26.22	34.25	23.51	5.75	2.55

more pronounced than the means indicate. The large standard deviations for distance scores and trial scores in learning Maze 2 are due to large scores by two or three animals. These high scores likewise raised the means considerably. There was practically no tendency, in learning Maze 2, to enter blind alleys on the

[10]The ratio consisted of 1 quart of skim-milk, 1 pound white bread, and 1 dessertspoonful of cod liver oil.

left side. With the exception of a slight confusion in the first one or two trials, the transfer of orientation to food direction was almost perfect in most of the animals. The true paths in the two mazes were probably too nearly identical to produce any interference. The discrimination in Maze 2 was too poor to make any reliability test by correlating the total scores from the two mazes. The best result was the fact that Maze 3, and very likely, therefore, Maze 2, was easily learned.

Experiment Ia

Procedure. Since food direction seemed to be the one habit that transferred effectively from learning Maze 3 to learning Maze 2, it was decided to transfer Series A of Experiment I to Maze 4. The true paths in Mazes 3 and 2 were nearly identical in direction and largely antagonistic to the true path in Maze 4. This meant that in learning Maze 4 the animals would have to break up the habits of going to the end of the maze; and they would have to avoid, as in previous learning, the first alley to the left, but take the second alley. Six days after completing learning in Maze 2, Series A was transferred to Maze 4.

Results. In the first few trials the interference of the previous experience in Maze 3 and Maze 2 was seemingly apparent. In the first trial, 18 out of 24 animals took the *a*-route and only one made a left turn. This was to be expected. But at the end of eight trials 13 rats still persisted in taking the *a*-route, and 70.8% of all the runs for the first eight trials were *a*- and *b*-response-patterns; whereas only 23.8% were *d*-, *e*-, and *p*-response-patterns. The evidence up to this point

seemed to favor strongly the presumption that interference was present and that it consisted of the orientation to food direction acquired in the first mazes.[11]

Experiment II

The results from the first few trials of Series A in Experiment Ia indicated the presence of negative transfer in such degree as to justify further experimentation. The relationship between learning Maze 2 and learning Maze 4 seemed to satisfy the requirement for a negative transfer procedure. This experiment was an attempt to test that relationship in a well-controlled experiment.

Procedure. Mazes 2 and 4 were selected for this experiment. The experimental animals were trained as follows: (*a*) complete learning of Maze 2, (*b*) rest three days, and (*c*) 40 trials in Maze 4. The controls were given only 40 trials in Maze 4. The experimental animals, Series B, consisted of 28 male rats ranging in age from 57 to 79 days. Series C, the controls, consisted of 16 male rats ranging in age from 60 to 70 days. The ages of both series of animals are given for the time the experimental animals began learning the first maze. The feeding and distribution of practice was the same as for Series A in Experiment I.

Results. The results from this experiment are presented under the following headings: (*a*) learning the interference habit, Maze 2, (*b*) differences in total time scores for Maze 4, (*c*) differences in total distance scores for Maze 4, (*d*) differences in response patterns.

[11]The training of Series A in Maze 4 was continued to 40 trials. The result will be presented in the discussion of Experiment II.

The results from Series A in learning Maze 4 are also presented. Differences between A and C should be taken only as suggestive. Series A was considerably older than C.

Learning the Interference. The mean total scores for time, distance, and trials for learning the interference, and the standard deviations of the total scores are presented in Table 9.

TABLE 9
MEAN TOTAL SCORES FOR DISTANCE, TIME, AND TRIALS
SERIES B, MAZE 2

	Distance	Time	Trials
Mean	86.50	162.1	7.22
S.D.	37.80	84.6	2.59

The significant fact brought out in this table is that Maze 2 was easily learned by all animals. In comparison with the mean total scores made by Series A in Maze 3[12] the mean total scores for Series B are consistently higher but not significantly higher, as the standard deviations indicate.

Differences in Total Distance Scores. For comparing the experimental and control animals in regard to improvement, the total trials (usually 40) were divided into divisions of four trials each. The total score in time and distance for each animal for each of these divisions of trials was computed. The means of these total scores for each division of trials were likewise computed. These means and the standard deviations for the total distance scores for Series B and C are

[12]See Table 8.

shown in Table 10. The total scores for larger divisions of trials are also presented. An examination of this table shows that there was a general tendency for more rapid improvement in Series C than in either B or A. The poorer scores of Series C in the first 20 trials are probably due to the fact that Series C had had no previous maze experience. But Series C not only caught up with Series B and A, but continued consistently to improve more rapidly. The mean total scores for Trials 25-40 show considerably better im-

TABLE 10
MEAN TOTAL DISTANCE SCORES AND STANDARD DEVIATIONS

Trials	Series B	Maze 4 Series C	Series A
1-4	124.96	118.62	104.37
S.D.	66.54	50.55	55.78
5-8	68.14	74.62	62.25
S.D.	20.18	18.79	23.56
9-12	61.00	71.81	54.67
S.D.	20.48	24.26	10.53
13-16	57.71	62.37	57.16
S.D.	11.83	17.73	15.20
17-20	61.39	64.25	56.41
S.D.	19.68	20.28	15.72
21-24	55.03	52.62	50.67
S.D.	14.40	10.83	18.91
25-28	54.25	49.12	52.04
S.D.	13.41	11.59	16.64
29-32	50.89	46.62	51.50
S.D.	12.71	12.88	15.38
33-36	48.28	40.87	48.66
S.D.	10.35	12.56	13.45
37-40	46.00	42.37	49.91
S.D.	10.74	10.09	12.84
25-40	199.39	179.00	202.12
S.D.	40.40	41.68	51.32
5-40	502.67	504.68	483.29
S.D.	88.77	71.24	85.29
1-40	627.64	623.31	587.66
S.D.	101.59	83.03	83.06

provement for Series C than for either of the other groups. It should also be noted that the agreement between Series B and A is rather close. One of the most suggestive facts revealed in this table is the absence of important differences between the series in the mean total scores for Trials 5-40, and for Trials 1-40. The advantage which Series C had in Trials 25-40 was clearly covered up, or offset, by the advantages which Series A and B had in Trials 1-20. The differences between the mean total scores for Series B and C and for Series A and C and the standard errors of these differences are given in Table 11. None of the differences are statistically significant as the critical ratios indicate.

The important finding thus far in these data was the tendency to better improvement in the control animals than in either experimental group. In both Series B and A there was very little improvement during the last 20 trials.

Differences in Time Scores. In view of the sub-

TABLE 11

DIFFERENCES BETWEEN EXPERIMENTAL AND CONTROL ANIMALS IN THE MEAN TOTAL DISTANCE SCORES, AND THE STANDARD ERRORS OF THESE DIFFERENCES

MAZE 4

Trials	B—C* Difference	B—C* $S.E._{m_1-m_2}$	A—C Difference	A—C $S.E._{m_1-m_2}$
33-36	7.41	3.70	7.79	4.17
37-40	3.63	3.23	7.54	3.64
25-40	20.39	12.91	23.12	14.78
5-40	—2.01		—21.39	

*Series B and A are experimental animals. Series C are control animals.

stantial correlations between distance scores and time scores as set forth in Chapter I, evidence of negative transfer might be expected in time scores as well as in distance scores. This, however, was not the case. The mean total time scores for the different divisions of trials and the standard deviations of the total scores are shown in Table 12. The differences between Series B and C and between Series A and C are practically negligible. The much higher mean for Series C than for Series B or A in Trials 1-40 is largely due to the practice effects in Series B and A from previous maze experience. The fact, however, that Series B and A did not have much lower mean total time scores than Series C indicates that negative transfer was very likely present, since the most pronounced gains from transfer in maze learning are in time scores.

Differences in Response Patterns. The differences between the practice animals and control animals in response patterns were determined (*a*) by finding the percentage which the frequency of each response pattern was of the total number of runs, and (*b*) by finding the average number of response patterns *a* and *dp*.[13]

[13]In this report the following designations of mazes, animals, experiments, and response patterns will be observed:

1. All mazes are designated by the Arabic numerals 1, 2, 3, and 4. The simplifications of these mazes will be designated 1*a*, 2*a*, 3*a*, and 4*a*. In all instances Mazes 2, 2*a*, 3, and 3*a* are interfering mazes used for learning the first, or interfering, habits. Mazes 1, 1*a*, 4 and 4*a*, are second problems used for testing the interference of first learning. See Figures 1 and 2 and also Table 3 in Chapter II.

2. All series of animals will be designated by capital letters.

3. All response patterns, responses, or runs, are designated by the small letters *a*, *b*, *c*, *d*, *e*, *f*, *p*. See Figures 3-8, Chapter II. These response patterns, responses, or runs are different routes the animals take in the maze. The *dp*-response-patterns are the *d*- and *p*-response-patterns taken together because they show the same orientation to food direction.

TABLE 12

MEAN TOTAL TIME SCORES AND STANDARD DEVIATIONS

Trials	Series B	Maze 4 Series C	Series A
1-4	187.85	209.68	125.91
S.D.	165.05	129.12	123.58
5-8	33.75	42.93	35.51
S.D.	14.09	17.54	56.09
9-12	26.70	32.83	20.99
S.D.	16.30	17.72	7.04
13-16	24.80	23.50	20.07
S.D.	11.47	8.24	11.77
17-20	29.20	23.60	19.75
S.D.	23.20	11.07	9.84
21-24	23.09	19.17	17.77
S.D.	9.50	6.22	7.32
25-28	21.26	16.85	17.74
S.D.	7.93	4.58	7.52
29-32	18.54	16.48	17.73
S.D.	5.95	6.35	9.00
33-36	17.28	16.23	16.48
S.D.	5.03	5.34	8.75
37-40	15.76	16.08	16.14
S.D.	4.29	4.67	6.75
25-40	72.85	65.65	68.10
S.D.	18.99	18.15	27.23
5-40	210.42	207.71	181.83
S.D.	62.38	34.28	79.54
1-40	398.27	417.39	307.76
S.D.	155.70	132.12	129.84

TABLE 13

PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN SERIES B ON MAZE 4

Trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	55.4	6.2	12.5	24.1	0.9	0.9
5-8	50.9	1.8	0.0	33.0	9.8	4.5
9-12	38.4	0.9	0.0	34.8	14.3	11.6
13-16	49.1	1.8	0.0	26.8	16.1	6.2
17-20	33.0	1.8	0.0	37.5	17.0	10.7
21-24	34.8	0.0	0.9	25.9	19.6	18.7
25-28	35.7	0.0	0.9	24.1	23.2	16.1
29-32	41.1	1.8	0.9	15.2	17.0	24.1
33-36	42.9	0.9	0.0	10.7	19.6	25.9
37-40	44.6	0.0	0.0	8.0	20.5	26.8
1-40	42.6	1.5	1.5	24.0	15.8	14.6

TABLE 14
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES C ON MAZE 4

	Response patterns					
Trials	*a*	*b*	*f*	*c*	*d*	*p*
1-4	34.2	4.7	10.9	40.6	0.0	9.4
5-8	26.6	1.6	0.0	60.9	6.2	4.7
9-12	9.4	1.6	0.0	40.6	45.3	3.1
13-16	10.9	0.0	0.0	31.2	54.7	3.1
17-20	4.7	6.2	0.0	29.7	57.8	1.6
21-24	6.2	0.0	0.0	21.9	60.9	10.9
25-28	12.5	0.0	0.0	20.3	45.3	21.9
29-32	10.9	1.6	0.0	17.2	37.5	32.8
33-36	14.1	0.0	0.0	10.9	21.9	53.1
37-40	18.8	0.0	0.0	7.8	28.1	45.3
1-40	14.8	1.6	1.1	28.1	35.8	18.6

TABLE 15
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES A ON MAZE 4

	Response patterns					
Trials	*a*	*b*	*f*	*c*	*d*	*p*
1-4	67.7	8.3	11.5	10.4	1.0	1.0
5-8	63.6	1.0	2.1	17.7	6.2	9.4
9-12	60.3	3.1	0.0	13.5	13.5	9.4
13-16	54.2	3.1	1.0	16.7	16.7	8.2
17-20	50.0	3.1	1.0	16.7	17.7	11.5
21-24	49.0	0.0	0.0	18.7	13.5	18.7
25-28	44.8	0.0	0.0	20.8	10.4	24.0
29-32	44.8	1.0	0.0	19.8	12.5	21.8
33-36	41.6	2.1	0.0	14.6	13.5	28.1
37-40	39.6	1.0	0.0	15.6	21.9	21.9
1-40	51.6	2.3	1.6	16.5	12.7	15.4

By method (*a*) the percentages were computed for the different divisions of trials so that changes in performance with practice might be studied. The data by the first method are presented in Table 13 for Series B, in Table 14 for Series C, and in Table 15 for Series A.

In comparing the percentages of response patterns for the different groups it should be kept in mind that

the first part of response pattern *a* and also of *b* consists of the true path to food acquired in learning Maze 2. A comparison of the tables reveals several important differences between the control series and the experimental series. The most noticeable differences are in the percentages of response patterns *a*, *d*, and *p*. The percentages for response pattern *a* are uniformly high for the experimental animals for all levels of practice. Moreover, the averages for 40 trials are 42.6 for Series B and 51.6 for Series A. The percentages of response pattern *a* for the control animals start with 34.2 for Trials 1-4 and then drop rapidly, leaving an average of only 14.8 for the 40 trials. It should be recalled here that Series A learned two interference mazes, Series B one interference maze, and Series C no interference before beginning learning in Maze 4.

The influence of the first maze learning is clear. It resulted in a pronounced increase in the percentages for response pattern *a*. There are no important differences between the different series of animals in the percentages of response patterns *b* and *f*. In the beginning trials, Series C made much larger percentages of *e*-response-patterns than did either B or A. The differences between the several groups in the percentages of these general exploratory responses are important only in beginning trials.

In comparing percentages of *d*- and *a*-response-patterns, one finds close agreement between Series A and Series B. The percentages of *d*-patterns are uniformly low. The highest percentage for any divisions of trials was 23.2. For Series C the percentage of *d*-

patterns increased very rapidly after the first four trials and the percentage for the 40 trials was more than double that of Series A or Series B. The percentages of response pattern *p* showed clearly better improvement in learning for Series C than for Series A or B. For Series C the percentages of perfect responses increased very rapidly in the later divisions of trials, whereas in the case of Series A and Series B no appreciable gains were made.

The predominant response pattern in the control group was *d* with a gradual decrease in it during later trials and a rapid increase in perfect responses. The predominant response pattern in experimental animals was *a*, with almost negligible gains in response patterns *d* and *p*. In the last eight trials Series A and B were still clinging tenaciously to response pattern *a*, whereas Series C was making a larger percentage of perfect responses than of all other responses combined.

These differences in performance between the control animals and practice animals show that the differences between these series of animals in total distance scores for the later trials of learning were not mere chance differences. They had back of them a persistent cause which, at the end of 40 trials, was still operating in the experimental animals with little apparent decrease in effectiveness. It is altogether unlikely that such differences in response were due either to the size of the groups, or to any lack of randomness of selection. Both the experimental procedure and the differences in response patterns point to the interference learning as the effective cause of retarded learning in

the experimental animals. The interference consisted of the transfer of the food-direction habit, or true response, acquired in learning the first maze. It seems very probable that the small, but consistent, differences between the control and experimental animals in the mean total distance scores for Trials 25-40 represented the combined effect of both positive and negative transfer.

The differences between the control and the experimental animals in the percentages of different responses indicated the possibility of significant differences in learning the direction of food. Response *a* was the only important pattern that could indicate clearly orientation to the end of the maze for food. But both responses *d* and *p* might show orientation to the side of the maze for food. The second method of treating the data on performance was, therefore, employed. The differences between the control and experimental animals in the number of *a*- and *dp*-patterns was determined. The mean number of each of these responses for the three series of animals in learning Maze 4 is presented in Table 16. The deviations of the distri-

TABLE 16

THE MEAN NUMBER OF *a*- AND *dp*-RESPONSE PATTERNS PER ANIMAL

MAZE 4

	Pattern *a*			Patterns *dp*		
Trials	Series B	Series C	Series A	Series B	Series C	Series A
1-20	9.00	3.37	11.83	3.68	7.31	3.71
S.D.	7.37	3.44	6.37	4.82	4.31	6.19
21-40	8.00	2.75	10.83	8.50	14.50	7.67
S.D.	7.00	4.35	7.84	7.52	6.48	7.93
1-40	16.85	5.75	20.00	12.36	21.82	11.25
S.D.	10.45	7.06	11.92	11.17	10.03	11.96

TABLE 17

DIFFERENCES BETWEEN THE CONTROL SERIES AND EXPERIMENTAL SERIES IN THE MEAN NUMBER OF *a*- AND *dp*-RESPONSE PATTERNS MAZE 4

Trials	Pattern *a* B-C*	A-C	Patterns *dp* B-C	A-C
1-20	5.63	8.46	—3.63	— 3.60
$S.E._{m_1-m_2}$	1.64	1.43	1.41	1.66
21-40	5.25	8.08	—6.00	— 6.83
$S.E._{m_1-m_2}$	1.71	2.24	2.15	2.29
1-40	11.10	14.25	—9.46	—10.57
$S.E._{m_1-m_2}$	2.65	3.00	3.27	3.49

*Series B and A are experimental animals. Series C are control animals.

butions are also given. These data are presented for the first and second halves of trials and for total trials. The differences between the means for the control series and experimental series and the standard errors of these differences are presented in Table 17. The critical ratios indicate that nearly all of the differences are significant. In the 40 trials in Maze 4, the *a*-patterns were characteristic of the performances of Series A and B, whereas *d*- and *p*-patterns were characteristic of Series C. The negative transfer resulted in significant differences in learning the direction of food in Maze 4.

Experiment IIa

The objectives in this experiment were (*a*) to counteract the positive transfer between Mazes 4 and 1 to such an extent that a fair test of reliability might be made by correlating the total scores for the two mazes, and (*b*) to equate as far as possible the control series and experimental series in the general practice effects from the maze experience in order to make the effects

of negative transfer stand out significantly if they were really present.

Procedure. This experiment was a continuation of Experiment II. The same animals (not including Series A) were used. The same distribution of practice and the same methods of feeding were employed. Series B had had (*a*) complete learning of Maze 2, (*b*) rest three days, and (*c*) 40 trials in Maze 4. Series C had had 40 trials in Maze 4 only. For further training the following procedure was adopted for Series B: (*a*) six days rest, (*b*) complete learning of Maze 3, (*c*) rest three days, and (*d*) 40 trials in Maze 1. After learning Maze 4, Series C was given a rest until entered into training for Maze 1 with Series B. There were good reasons to believe that this procedure would meet the requirements of the experiment. The general practice effects from maze experience were probably about equal for the two series of animals at the end of Experiment II. Since learning Maze 2 interfered with learning Maze 4, it seemed very likely that learning Maze 3 would interfere with learning Maze 1 to such an extent as to offset in some measure the positive transfer between Maze 4 and Maze 1. It should be noted here that this procedure had some other possible advantages. (*a*) For Series B the learning in both Maze 4 and Maze 1 would be learning with interference so that negative, or zero, correlations between the two mazes should not result. (*b*) In Maze 1 the alleys to the left side of the box were closed so that the food-direction habit acquired in Maze 4 could not transfer to Maze 1 in the form of a definite response pattern. This meant,

for the most part, that only positive transfer effects from Maze 4 should appear in learning Maze 1. The control animals, therefore, should be practically free from negative transfer and show optimum improvement.

Results

Learning the Interference. The second, or interpolated, interference problem, Maze 3, was learned by Series B with considerable positive transfer. The mean number of trials was 4.96 and the standard deviation was 2.40. This was similar to the result obtained from Series A, Experiment I, in learning Maze 2 after learning Maze 3. Some slight disturbance appeared in the first trial, but most of the animals required only four or five trials to satisfy the criterion of complete learning. This positive transfer was to be expected. Previous experience in Maze 4 could not transfer negatively since the left side of the box was closed, that is, the left side alleys are not a part of Maze 1. Moreover, the animals which had persisted in response pattern *a* in running Maze 4 had fixated the true route to food for Maze 3. But the positive transfer was a real advantage since the purpose of complete learning in Maze 3 was to re-establish the interference habit in all animals before beginning learning in Maze 1.

Reliability. The results bearing on this aspect of the problem of these experiments have been presented in Chapter II. Positive transfer effects were counteracted as the data that follow will show.

Differences in Total Distance and Total Time Scores. The mean total scores for time and distance

TABLE 18
MEAN TOTAL SCORES AND STANDARD DEVIATIONS
MAZE 1

Trials	Distance Series B	Distance Series C	Time Series B	Time Series C
1-4	122.25	96.93	118.94*	77.76
S.D.	48.61	37.72	72.04	40.25
5-8	55.46	47.50	28.92	20.91
S.D.	15.27	14.42	13.97	9.72
9-12	55.46	42.75	24.32	16.75
S.D.	14.31	7.61	7.39	3.82
13-16	57.96	40.00	26.40	17.98
S.D.	18.05	10.82	11.28	6.40
17-20	48.92	36.50	20.77	13.97
S.D.	14.57	10.49	8.49	4.03
21-24	44.92	35.75	19.05	11.83
S.D.	12.63	10.14	5.92	3.43
25-28	44.14	34.50	17.85	13.33
S.D.	13.68	9.86	6.92	4.57
13-28	195.96	153.00	84.07	56.12
S.D.	44.75	49.62	24.07	14.89
5-28	306.89	237.00	137.32	93.78
S.D.	65.31	52.70	35.72	23.56
1-28	429.14	333.93	253.42*	171.55
S.D.	88.42	58.92	82.74	37.28

*26 cases.

for Series B and C are presented in Table 18. The one outstanding fact in this table is the better learning of Series C. For every level of practice for both time and distance scores the means for Series C are lower in magnitude than those for Series B. This is true also for the larger divisions of trials including Trials 1-28. By the end of 8 trials Series C had attained a level of learning, in terms of distance scores, not reached by Series B in 28 trials. The differences between the mean total scores for Series B and C, and the standard errors of the differences, are shown in Table 19. The differences between Series B and C in the means of total distance scores range from about three times the

TABLE 19

DIFFERENCES BETWEEN THE MEAN TOTAL SCORES OF SERIES B AND C AND THE STANDARD ERRORS OF THESE DIFFERENCES

MAZE 1

Trials	Distance B-C	Distance $S.E._{m_1-m_2}$	Time B-C	Time $S.E._{m_1-m_2}$
21-24	9.17	3.48	7.22	1.43
25-28	9.64	3.57	5.52	1.75
13-28	42.96	11.20	27.95	5.94
5-28	69.89	18.05	43.54	9.05
1-28	95.21	22.27	81.87	18.71

standard errors to more than four times the standard errors. The differences between Series B and C for total time scores are more than four times the standard errors. That interference was operating in Series B in this experiment seems altogether conclusive. The differences in both distance and time scores were significant. The causes of the interference might be inferred, but the manner in which the interference took place is not at all evident in the differences between the experimental and control animals in mean total distance or total time scores. The only recourse that seems promising is analysis of performance.

Differences in Response Patterns. In learning Maze 4, Series B and C showed some very significant differences in response patterns. The prevailing response in Series B was response pattern *a*, whereas in Series C the prevailing response was *d*. Negative transfer was clear not only in the transfer of response patterns from previous learning but in the fact that this transfer interfered significantly with learning the new direction of food. The response patterns made in learning Maze 1 did not present such a clear case in

favor of negative transfer. In Tables 20 and 21 it will be seen that there were no appreciable differences between Series B and Series C in the percentages of *a*-response-patterns. The big differences were in the percentages of general exploratory responses, and in the responses showing that the direction of food had been learned. Series B had much larger percentages of *b*- and *e*-responses than Series C. In this respect Series B gave indications of learning a new habit. Series C had larger percentages of *d*-runs, and much larger percentages of perfect responses. In view of these data two facts require explanation. (*a*) The differences between the control animals and the experimental animals in total distance and total time scores were significant. (*b*) No response pattern from previous learning transferred negatively and persistently.

The first of these facts can be explained in terms of the percentages of response patterns. In comparison with Series C, the much higher averages for Series B were due to the much larger percentages of response patterns *b* and *e* and the lower percentages of perfect responses. The question at once arises as to why Series B should have larger percentages of the less economical, or exploratory, response patterns. This is very closely connected with the explanation of the second fact.

No response pattern from previous learning transferred negatively and persistently because there was none that could transfer from previous learning to the learning in Maze 1. The number of response patterns possible in either Maze 4 or Maze 1 was limited by the

TABLE 20
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES B ON MAZE 1

Trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	27.7	12.5	33.0	13.4	0.0	13.4
5-8	16.1	6.2	3.6	26.8	7.1	40.2
9-12	14.3	5.4	0.9	29.5	21.4	28.6
13-16	14.3	1.8	0.9	36.6	24.1	22.3
17-20	13.4	0.0	0.0	21.4	27.7	37.5
21-24	12.5	0.0	0.0	13.4	33.0	41.1
25-28	8.0	0.0	0.0	15.2	34.8	42.0
1-28	15.2	3.7	5.5	22.3	21.2	32.1

TABLE 21
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES C ON MAZE 1

Division trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	34.4	6.2	26.6	9.4	10.9	12.5
5-8	15.6	0.0	6.2	7.8	32.8	37.5
9-12	18.7	0.0	0.0	4.7	39.1	37.5
13-16	10.9	3.1	1.6	1.6	25.0	57.8
17-20	12.5	1.6	0.0	0.0	23.4	62.5
21-24	10.9	0.0	0.0	0.0	23.4	65.6
25-28	7.8	0.0	0.0	1.6	18.7	71.9
1-28	15.8	1.6	4.9	3.6	24.8	49.3

situation as the analysis of performance has shown. There were three definite uniform response patterns, *a, d,* and *p,* and three less uniform, uneconomical response patterns, *e, b,* and *f*. A comparison of the four learning situations, Maze 2, Maze 4, Maze 3, and Maze 1, shows that neither the response pattern *d* nor *p,* as found in Maze 1, could have been transferred from learning in the other mazes. In learning those mazes, moreover, the responses *e, b,* and *f* for Maze 1 surely had not been previously practiced. The response pattern *a* did not appear in learning Maze 1 as

a prevailing, persistent response because previous learning in Maze 4 made that impossible. In learning Maze 4 the prevailing response pattern for Series B was *a*, that is, response *a* for Maze 4. But response pattern *a* for Maze 4 is clearly antagonistic to response pattern *a* for Maze 1. Consequently, when the animals returned from the end of the maze in running Maze 1, they retraced the main alley, because response pattern *a* for Maze 4 which had been automatized in a long succession of trials prevented entrance into the food alley for Maze 1. The facts show that this probably did happen. The performances in the first trial in Maze 1 show that 26 out of 28 animals went to the end of the maze in the first trial. Of these 26, only 5 completed *a*-runs for Maze 1, but 21 made *f*-runs. The 21 went to the end of the maze, but when they returned they retraced the main alley. The food-direction habit acquired in Maze 4 and aggravated by learning Maze 3 was the determining factor, but, since the left side of the maze was closed, there was no definite response pattern that could transfer negatively. The consequence was a prolonged stage of general exploratory responses with large time scores. But these responses were too uneconomical and lacking in uniformity for automatism and prolonged repetition.

There is one more fact that supports this explanation in a very suggestive manner. The mean total scores for time and distance gave some indication that the time per distance run was longer for Series B than for Series C. The ratios of the mean total time scores to the mean total distance scores for the different divi-

TABLE 22
THE RATIOS OF THE MEAN TOTAL TIME SCORES TO THE MEAN TOTAL DISTANCE SCORES
SERIES B AND C ON MAZE 1

Series	Trials 1-4	5-8	9-12	13-16	17-20	21-24	25-28
B	1.02	.51	.44	.45	.42	.42	.40
C	.80	.44	.39	.45	.38	.33	.35

sions of trials were determined. They are shown in Table 22. They indicate that previous learning tended to *confuse* the animals in learning Maze 1. The absence of any definite response patterns that might transfer negatively, or in accord with the food-direction habits from previous learning, not only produced an *increased percentage of exploratory responses* but an increase in time per distance run. This is almost analagous to complexes in humans. Previous experience left the animals confused because there was no outlet in the new situation for previously automatized relevant response patterns.

SUMMARY

1. In Experiment I it was found that the habit of taking left turns and avoiding alleys to the right side of Maze 3 did not transfer to Maze 2 as a tendency to enter blind alleys to the left. Consequently, the transfer was positive. The food-direction habit acquired in Maze 3 transferred in learning Maze 2. The true paths in the two mazes were, therefore, too nearly identical to produce any interference.

2. Learning Maze 4 after learning Mazes 2 and 3 resulted in much negative transfer. In the first eight

trials 70.8% of all runs were *a*- and *b*- response-patterns. The perfect response acquired in learning Mazes 2 and 3 transferred persistently to the learning of Maze 4.

3. Complete learning of Maze 2 by 28 animals interfered considerably with learning Maze 4. This is brought out by a comparison with the results of the control group. (*a*) The mean total distance scores for different divisions of trials indicated positive transfer in the first 16 trials but negative transfer in the last 16 trials. (*b*) As compared with the control animals, the experimental animals were retarded in learning at the end of 40 trials. In the last 20 trials the experimental animals made very little progress. This period was largely a plateau. (*c*) The mean total time scores showed no considerable differences between the control and experimental animals during the later divisions of trials. This was evidence that negative transfer must have been present in no small degree, since transfer in maze learning usually results in very large improvement in time scores. It was also evidence that the time per distance run was lower for the experimental animals than for the control animals, since the differences in mean distance scores were considerable. This difference in rate of running was probably due to a high degree of automatism in the experimental animals, since the interference learning resulted in persistently large percentages of response pattern *a*. (*d*) An analysis of the performance of the experimental and control animals showed that, with little variation from one division of trials to another, approximately 45% of all responses made by the experimental animals

were *a*-response-patterns. This was the cause of the learning plateaus in the experimental animals. This was negative transfer since the first part of response pattern *a* consisted of the true path to food in learning Maze 2. The prevailing response pattern in the control animals was *d*, the percentages of which decreased rapidly in later trials with a marked increase in perfect responses. (*e*) The differences between the experimental and control animals in the mean number of *a*- and *dp*-response-patterns were from three to five times their standard errors. This was true for the first 20 trials, the last 20 trials, and for total trials. This was evidence that the previous maze learning interfered significantly with learning the direction of food in Maze 4.

4. In comparing the experimental procedure—complete learning of Maze 2, rest three days, 40 trials in Maze 4, rest six days, complete learning of Maze 3, rest three days, and 28 trials in Maze 1—with the control procedure—40 trials in Maze 4, 15 days rest, and 28 trials in Maze 1, the following results were obtained: (*a*) The differences between the control and experimental animals in the mean total distance scores and mean total time scores in learning Maze 1 were significant for five different divisions of trials, including total trials. All divisions of trials showed much poorer improvement in the experimental animals. (*b*) The analysis of performance showed larger percentages of *b*- and *e*-responses and lower percentages of perfect responses for the experimental animals than for the control animals. (*c*) The experimental ani-

mals did not make large percentages of response *a* in learning Maze 1 because that pattern was inhibited by response *a* for Maze 4 which had been highly automatized in previous learning. (*d*) Interference was present in a negatively transferred food-direction habit from previous experience, but there was no outlet through a relevant automatized response pattern. The result was increased time per distance run, and random, or general exploratory responses.

IV

NEGATIVE TRANSFER UNDER THE CONDITIONS OF OVERLEARNING AND STRONG FOOD INCENTIVE

The trend of the differences in performance and total distance scores between the control and the experimental animals in Experiment II indicated that the interference might be much more effective and more apparent (*a*) if the interference habit were overlearned, (*b*) if a stronger food incentive were developed, and (*c*) if large groups of animals were used. The differences between Series B and C in the mean total distance scores for later learning in Experiment II were not statistically significant, but the cause of those differences still persisted in the experimental animals at the end of 40 trials with little depreciation. Series A, moreover, showed consistently larger percentages of *a*-response-patterns than Series B. Series A had learned two very similar interference habits before beginning Maze 4, whereas Series B had learned only one. It seemed, moreover, that some of the exploratory responses in the early divisions of trials in Experiment II might be due to fluctuations in incentive. Stronger incentive might mean better learning in the control animals, but increased automatism of the interfering response patterns in the experimental animals.

Experiment III

Procedure. The procedure in Experiment III was

accordingly changed slightly from that of previous experiments. Sixty-one male rats, aged 44 to 55 days, were divided into two series: Series D, 34 experimental animals, and Series E, 27 control animals. The experimental animals were given the following training: (*a*) complete learning of Maze 3, (*b*) three days' rest, (*c*) complete relearning of Maze 3, (*d*) rest three days, and (*e*) 40 trials in Maze 1. Series E were trained only in Maze 1, beginning learning in it with Series D. The animals were all placed on the experimental diet seven days before Series D had the first trial in Maze 3. The diet was composed of the same foods as used in the earlier experiments, but the time of eating was limited to six minutes instead of eight. Moreover, in this experiment there was additional quantitative stinting at the beginning of learning in each maze. On the day of the first trial in either maze only half time was allowed for eating. On the day previous to the day of the first trial no food was given to the animals.

Results

Learning and Relearning the Interference. The complete learning and relearning of Maze 3 was selected for interference. It was not the purpose of this experiment to determine the influence of different degrees of incentive or the influence of overlearning upon learning, but to study the changes in performance under the conditions of increased interference. In learning Maze 3, however, Series D in this experiment differed very appreciably from other series of experimental animals. The influence of overlearning upon interference does not, of course, appear in this connection.

TABLE 23

MEAN TOTAL SCORES AND STANDARD DEVIATIONS FROM LEARNING INTERFERENCE MAZES BY DIFFERENT SERIES OF EXPERIMENTAL ANIMALS

	N	Maze	Distance	Time	Trials
Series D	34	3	41.73	67.94	4.74
S.D.			19.62	31.67	1.47
Series A	24	3	69.87	130.69	6.76
S.D.			27.68	63.60	2.55
Series B	28	2	86.50	162.10	7.22
S.D.			37.80	84.60	2.59
Series N	14	3	61.00	107.85	6.07
S.D.			27.59	47.42	1.78

The influence of incentive probably does. The results, therefore, from the interference learning by Series D are presented with the results from other groups. The mean total scores for complete learning by Series D and three other series of experimental animals are presented in Table 23. The diet for Series D was qualitatively similar but quantitatively different from that of Series A and B. In addition to quantitative stinting in beginning trials, Series D was given only six minutes instead of eight for eating. But Series A and B were much older animals than D. Series B, moreover, had learned Maze 2 instead of Maze 3. Consequently, any differences between Series A and B, on the one hand, and Series D, on the other, can be only suggestive. These differences, whatever may have been their causes, were large, as Table 23 indicates. The data from Series N and Series D, however, are comparable. Series N was a group of 14 male rats, aged 60 days at beginning learning.[14] Their diet con-

[14]The full data on Series N and its control are presented in Chapter VII.

sisted of white bread, whole milk, and cod liver oil. They were fed once a day, to satiation, but not over ten minutes. The only other important differences between D and N were (*a*) the season of running (Series D was run in the spring, Series N in the winter) and (*b*) the possible lack of randomness of selection, since these two series were made up of altogether different litters. These two differences may not have been important. In Table 23 it will be seen that the differences between D and N in the mean total scores were considerable. They are not statistically significant, but the critical ratios are approximately 2.5 for all three criteria. That Series D made much better improvement in learning the interference maze than Series N and other series of experimental animals is evident.

The data from relearning also support this conclusion. The only comparison that can be made here is with Series N. The criterion of complete learning in the relearning of Maze 3 was three consecutive perfect trials. In this relearning test every animal in Series D satisfied the criterion in three trials. As far as distance errors and other errors in performance were concerned, relearning showed perfect retention. In Series N, ten animals required only three trials, two required six trials, and two required seven trials. In view of these slight differences between Series D and N in the amount of practice in relearning, the best evidence of better learning, or better retention, in Series D was the difference in automatism in the perfect trials. The mean time score per trial for the perfect trials which satisfied the criterion for complete relearning of

Maze 3 was 2.48 seconds for Series D and 3.93 seconds for Series N. The standard deviations for the distributions were .73 and 1.66, respectively. These averages and standard deviations were for 102 scores for Series D and 42 scores for Series N. The difference between the means is 1.45. The standard error of the difference is ±.256. Since time was taken in the same way, with the same care, by the same observer, and with no thought of using the scores in this connection, it seems altogether probable that these differences were due to the difference in incentive. This finding is in agreement with the results obtained by Anderson and Smith (40). Of course the better time scores for Series D might be evidence only of better incentive at the time without better learning or better retention. But the lower averages made by Series D in first learning and relearning lend support to the conclusion that the differences were due to better learning, or better automatism, of the interference habit.

Differences in Total Distance Scores and Total Time Scores. The method used for determining the differences between Series D and Series E in mean total scores is the same as that used in treating the data from Experiment II. The progress of the experimental and control animals in learning Maze 1 was determined by obtaining the mean total scores for different divisions of trials. These are shown in Table 24. A comparison of the mean total distance scores for these two series of animals reveals a general similarity to the findings in Experiment II. Series D, the experimental animals, have the advantage during the first 16 trials, but Series

E, the control group, continued to improve more rapidly. This trend is also evident in the total time scores for different divisions of trials. The more important differences and their standard errors are shown in Table 25. The differences for the latter part of the practice period in time as well as distance are significant. For Trials 5-40 they are approximately two times their standard errors. The outcome of this experiment was similar to that of Series B and C in Experiment II, but the differences were greater and more significant.

TABLE 24

MEANS OF TOTAL SCORES AND STANDARD DEVIATIONS

	Distance		Time	
Trials	Series D	Series E	Series D	Series E
1-4	61.94	81.59	48.98	129.66
S.D.	28.55	32.46	36.91	69.60
5-8	65.53	66.48	37.86	35.09
S.D.	23.55	15.37	27.67	16.40
9-12	57.23	57.18	25.80	20.90
S.D.	19.88	16.49	18.84	8.42
13-16	53.05	53.70	20.54	21.70
S.D.	17.63	17.74	10.90	9.66
17-20	51.17	46.66	19.10	18.65
S.D.	15.68	10.07	9.51	7.14
21-24	50.47	44.89	19.04	16.20
S.D.	14.69	10.30	8.08	5.27
25-28	48.70	41.33	18.68	15.04
S.D.	13.25	8.45	7.03	4.75
29-32	49.58	38.44	17.72	13.78
S.D.	16.21	8.78	7.95	4.60
33-36	48.91	37.11	17.15	12.20
S.D.	15.49	8.90	7.08	3.71
37-40	45.41	36.00	15.40	11.90
S.D.	11.75	8.71	5.11	3.60
25-40	192.61	152.88	68.96	52.93
S.D.	51.55	31.12	22.74	13.41
5-40	470.08	421.81	191.32	165.48
S.D.	108.66	81.67	58.56	40.02
1-40	532.03	503.40	240.30	295.15
S.D.	108.51	89.48	70.04	75.72

TABLE 25

DIFFERENCES BETWEEN THE EXPERIMENTAL AND CONTROL ANIMALS IN THE MEAN TOTAL SCORES FOR DIFFERENT DIVISIONS OF TRIALS, AND THE STANDARD ERRORS OF THESE DIFFERENCES

MAZE I

	D-E*			
	Distance		Time	
Trials	Difference	$S.E._{m_1-m_2}$	Difference	$S.E._{m_1-m_2}$
33-36	11.80	3.16	4.95	1.41
37-40	9.41	2.62	3.50	1.12
25-40	39.73	10.68	16.03	4.68
5-40	48.27	24.38	25.84	12.65

*Series D are experimental animals and Series E are control animals.

Differences in Response Patterns. The real meaning of the differences between Series D and Series E in total distance and total time scores does not appear in the mere quantitative expressions of distance and time. They, in themselves, reveal no causes for the learning plateau in Series D and no causes for the steady continued improvement of Series E. It can only be inferred that the differences are due to the experimental factor, since the only important difference between the two series of animals was interference in Series D. But, if, in addition, an analysis of the performance of the control and experimental animals indicates the actual presence of negatively transferred response patterns as the probable cause of the differences, we can be doubly sure of the significance of the findings. This seems to be the case as the analysis of the response patterns indicates. The percentage of trials for each response pattern is given in Table 26 for Series D and Table 27 for Series E. These data show the same trend as was evident in the analysis of the response patterns of Series

A, B, and C in Experiment II. But they also show more than the same trend. In Series D, 84.6% of the responses in the first division of trials were *a*-runs, and the average for 40 trials is more nearly comparable with that of Series A than with that of Series B. In Series E the percentage of *e*-runs was much lower all through the course of learning than was the case for Series C. The percentages for 40 trials were 12.9 for Series D and 28.1 for Series C. The percentage of the more exploratory *b*- and *f*-responses were likewise decreased. The percentage of perfect responses, moreover, was nearly twice as great for Series E as for Series C.

In view of the difference in age between the animals of Experiment II and those of this experiment, the differences between the two control series, E and C, and between the experimental series, D and A or B, might be ascribed to age. Age was possibly a factor, but the similarity between the experimental series and the control series for the two experiments is pronounced. This

TABLE 26
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES D ON MAZE 1

Trials	Response patterns					
	a	*b*	*f*	*e*	*d*	*p*
1-4	84.6	0.7	8.1	1.5	0.0	5.1
5-8	55.1	2.9	5.9	17.6	2.2	16.2
9-12	49.2	1.5	1.5	20.6	11.8	15.4
13-16	45.6	2.2	0.7	15.4	19.1	16.9
17-20	44.1	0.0	0.7	13.2	23.5	18.4
21-24	43.4	0.0	0.7	12.5	25.0	18.4
25-28	37.5	0.7	0.0	14.7	24.3	22.8
29-32	38.2	1.5	0.0	14.7	21.3	24.3
33-36	42.6	0.0	0.7	11.8	23.5	21.3
37-40	45.6	0.0	0.0	8.8	18.4	27.2
1-40	48.6	1.0	1.8	13.1	16.9	18.6

TABLE 27
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES E ON MAZE 1

Trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	57.4	5.5	13.0	14.8	3.7	5.5
5-8	20.4	2.8	0.9	44.4	23.1	8.3
9-12	14.8	0.9	0.0	31.5	38.0	14.8
13-16	6.5	0.0	1.9	18.5	53.7	19.4
17-20	6.5	0.0	0.0	6.5	63.9	23.1
21-24	6.5	0.0	0.0	5.6	61.1	26.8
25-28	9.3	0.0	0.0	2.8	51.8	36.1
29-32	10.2	0.0	0.0	0.0	43.5	46.3
33-36	9.3	0.0	0.0	3.7	35.2	51.8
37-40	10.2	0.0	0.0	0.9	33.3	55.5
1-40	15.1	0.9	1.6	12.9	40.7	28.8

similarity, however, is no more outstanding than the dissimilarity between the experimental and control series in each experiment. So far as the character of performance is concerned in these experiments, age is a relatively insignificant factor as compared with the influence of interference learning.

The location of the interference in this experiment was the same as in Experiment II. A comparison of the percentages of trials for each response pattern for Series D and E shows that the interference in D consisted of the persistently large percentages of *a*-responses. The first part of the *a*-response pattern was an exact repetition of the true path to food in Maze 3. Series E, the control animals, also made a large percentage of *a*-responses in the first four trials, but this percentage rapidly decreased. The *a*-response did not become a persisting habit in Series E. The *a*-response-pattern was more than a fixated chance route to food. The differences between the control and experimental animals in the percentages of *b*- and *f*-responses were

TABLE 28
MEAN NUMBER OF RESPONSE PATTERNS *a* AND *dp* PER ANIMAL
MAZE 1

Trials	Pattern *a* Series D	Pattern *a* Series E	Patterns *dp* Series D	Patterns *dp* Series E
1-20	11.11	4.22	5.17	10.14
S.D.	6.74	3.97	6.02	5.14
21-40	8.26	1.81	9.08	17.63
S.D.	8.78	4.30	9.35	4.73
1-40	19.38	6.03	14.26	27.81
S.D.	14.48	7.57	14.77	8.43

slight. But in the case of *d*-responses, and perfect responses in both of which the animal took the right direction for food, Series E, the control group, was clearly superior to Series D, the experimental group.

The importance of these differences in learning the general direction of food was developed in another method. The average number of *a*- and *dp*-response-patterns for each series of animals was determined for the first 20 trials, for the second 20 trials, and for total trials. These data and the standard deviations are presented in Table 28. The large standard deviations for Series D in the last 20 trials and for total trials was due to skewed and slightly bimodal distributions. The *a*-response was the prevailing pattern in Series D, but a few animals in each experiment seemed to be altogether free from interference. This agrees with the findings in other studies of interference.[15] The performance of experimental animals that are free from interference is similar to the performance of control animals. The absence of *a*-runs after the first few trials usually means a greater frequency of response

[15]See (7, 8, and 35).

patterns *d* and *p*. In Series E, the control group, the distributions are skewed, but not bimodal. The distributions of *a*-runs are much skewed toward higher scores, whereas the distributions of *d*-runs are skewed toward lower scores. It does not seem likely that these departures from the normal curve will affect the reliability of the differences to any great extent.

The differences between Series D and E in the mean number of *a*- and *dp*-response-patterns and the standard errors of these differences are presented in Table 29. The critical ratios are on the average about four to one. Some are lower, but some are higher. The reliability of the differences seems assured. The real importance of the differences consists, moreover, in the fact that they are large as compared with the means themselves.

The conclusion that seems most plausible in view of this data is that the food-direction habit acquired in learning Maze 3 materially interfered with learning the new direction of food. Series E, the controls, made a large percentage of *a*-responses in the first four trials. This was also true of the control animals in Experiment II, but both series very soon switched over to *d*- and

TABLE 29

DIFFERENCES BETWEEN THE EXPERIMENTAL ANIMALS AND CONTROL ANIMALS IN THE MEAN NUMBER OF RESPONSE PATTERNS *a* AND *dp*

	D-E			
	Pattern *a*		Patterns *dp*	
Trials	Difference	$S.E._{m_1-m_2}$	Difference	$S.E._{m_1-m_2}$
1-20	6.89	1.39	— 4.97	1.43
21-40	6.45	1.72	— 8.55	1.87
1-40	13.35	2.88	—13.55	2.84

p-response patterns. The larger percentage was *d*-runs, which means the animals took the first turn to the right side of the maze. This shift in performance from *a*- to *d*-responses was made in spite of the fact that the *a*-response is just as economical as *d* in distance and time. The relative efficiency in time and distance of the different response patterns is clearly not the only factor in the selection of responses. The response patterns *a, d,* and *p* are not simply successions of response elements, mere linkages, due to frequency or recency of association. They are unitary responses and their elements are determined by some organizing factor. The response system might well be called in this instance a food-direction habit, but the unity of such a response pattern, or system, is probably due to something more inclusive and compelling than contiguity of the associated elements.

SUMMARY

1. Two series of male rats with an average age of 51 days were used in this experiment. The experimental group, Series D (34 animals), was trained to complete learning and relearning of Maze 3, the interference. Both Series D and Series E (27 animals) were given 40 trials in Maze 1.

2. The interference habit was overlearned by means of a relearning test given three days after first learning. Incentive was intensified, first, by quantitative stinting all through learning, and, secondly, by additional stinting at the time of beginning learning in each maze.

3. Learning the interference, Maze 3, revealed

some clear evidence that intensifying food incentive (*a*) improved first learning, and (*b*) significantly improved the retention of the automatism of the perfect response.

4. The differences between Series D and Series E in both the mean total distance scores and the mean total time scores for the last 16 trials were significantly in favor of better learning for the control animals. For Trials 5-40 the differences were two times their standard errors and likewise in favor of better learning in the control animals.

5. *All through the different levels of practice the* control animals improved consistently both in time and distance scores as the averages for each level of practice indicate, but for over 20 trials the experimental animals made almost no progress in distance scores.

6. The cause of the interference, or retarded learning, in Series D was the persistently large percentages of *a*-response-patterns. The first part of response *a* consisted of what was the perfect response in learning Maze 3. A large percentage of *a*-responses was also made by the controls in the first four trials, but they very rapidly shifted from this response to responses *d* and *p*.

7. The differences between Series D and Series E in the mean number of *a*- and *dp*-responses were approximately four times their standard errors. By the end of 12 trials over 50% of the control animals had the general direction of food. By the end of 20 trials this percentage was increased to 89. But the largest percentage of *dp*-responses for the experimental ani-

mals in any level of practice was 47. The food-direction habit acquired in learning the interference, Maze 3, interfered significantly with learning the new direction of food.

V

NEGATIVE TRANSFER IN VERY YOUNG RATS

The results from Experiments II and III indicated that interference can persist over a long period of training and in such degree as to retard learning significantly. It appeared also that interference was most pronounced under the conditions of strong incentive and of overlearning the interfering habit. Both of these conditions were conducive to a high degree of automatism.

In view of these findings, it seemed that the most crucial test of interference would be in experiments with very young rats. If the spread in influence of any negatively transferred habit should be great, and if such a habit should be developed in the early stage of immaturity, its influence might be far more detrimental than when developed later. On the other hand, it seemed possible that poorer learning ability, poorer retention, or poorer automatism of the response pattern (due to poor motor coordination) might exclude interference altogether in the very early stages of immaturity, or reduce its duration to the point where its influence would be negligible. In Experiment IV, therefore, very young rats were used. It was decided to develop the interfering habit at the earliest age possible using food incentive.

Experiment IV

Procedure

Animals. Three series of male rats—(*a*) Series F,

31 experimental animals, (*b*) Series G, 25 learning-control animals, and (*c*) Series H, 28 growth-control animals—were made up in the following manner. Series F and G were weaned on the eighteenth day of age. Series H was not weaned until three days before beginning training, but not later than the thirtieth day of age. The groups were made up at the time of weaning Series F and G. Only litters with three or more normal males were used. Each litter contributed to each series. The selection of mates for the three series was done according to the nearest like weight, excluding all littermates that were outside a range of differences of five grams. But all littermates within that range were placed in one of the three series in such a way as to keep the series as nearly equal in weight as possible. The mean weight per animal in grams, the mean difference between the littermates for the different series, and the standard deviations of these distributions are given in Table 30. The weights of the animals were taken to the nearest half gram. The maximum difference between any two littermates was 4.5 grams. Of all the differences, only six were above 2.5 grams. The differences in mean weight for the

TABLE 30

Mean Weight in Grams per Animal, Mean Difference between Littermates for Different Series, and Standard Deviations of Distributions

	Mean weight (Grams)			Mean differences between littermates (Grams)		
	Series F	Series G	Series H	F-G	F-H	G-H
Mean	21.79	21.65	22.07	1.016	1.177	1.550
S.D.	3.90	4.01	4.06	.690	1.104	.969

three series are almost negligible, and the standard deviations are approximately equal for the three series.

The weaning of Series F and G at 18 days of age introduced several problems. The first was to get the weaned rats to eat. This was especially urgent since it was decided to begin training the experimental animals, Series F, at 20 days. The diet consisted of white bread soaked in whole sweet milk with cod liver oil. On the first few days after weaning, the food was left in the cage for a half-hour. The animals were aroused, and the dish of food was placed in the nest. Those animals that would not touch it at the second feeding were introduced to it by pressing their snouts gently into the wet feed. This may not have been necessary, but in several cases it very obviously hastened their first eating. All animals in Series F and G had learned to eat by the twentieth day. The time for eating was gradually reduced from one-half hour during the first four or five days after weaning to five minutes after each trial in learning Maze 1.

The most difficult problem was that of handling the growth-control group, Series H. The weaning of Series F and G left all litters abnormally small in number. It seemed absolutely necessary to keep the litters normal in size so that Series H would represent normal development. To increase these litters to normal size the following methods were employed. In most instances there were two or more litters of the same age in days. In this case the mother with the larger litter, and especially with the larger number of males, was selected to be the mother for two litters of the H series.

If the litter was still too small it was increased in size to six or seven by adding young females. When only one litter was organized, the control mother was given additional rats from the females of large litters of slightly older, or slightly younger, rats, selecting those similar in size to those of her own litter. In no case was any mother given a larger litter than she had had previous to weaning the F and G series. The rats that were transferred to other mothers showed no indications either in weight changes, or in any other way, of being poorly fed, or out of place. Not a single one was lost as a result of the transfer, and not one had to be discarded because of depreciation in rate of growth in weight.

The mean weight and the standard deviations of the distributions for the three series at 28 and 40 days of age are presented in Table 31. The slight differences between Series F and G were probably of no consequence. At 28 days of age, the mean for Series H is considerably higher than for Series F and G. This may have been due partly to the fact that Series F and G were weighed before being fed, whereas Series H were not yet weaned. The reason for the lower weight of Series H at 40 days of age is not clear. All litter-

TABLE 31
MEAN WEIGHT IN GRAMS OF YOUNG RATS AT TWO DIFFERENT AGES

Age	Series F	Series G	Series H
28	35.46	35.39	38.75
S.D.	6.78	5.79	5.42
40	72.33	71.23	68.89
S.D.	13.91	12.58	12.06

mates were caged together and Series H had then been on the experimental diet for ten days at least. From the standpoint of weight, it seems that the weaned animals suffered no disadvantage from the the very early weaning.

Learning Procedure. The distribution of practice was two trials a day, one in the morning between 7:30 and 10:00 o'clock, and the other in the evening between 7:00 and 9:30 o'clock.[16] Two trials a day instead of one were given because the first requisite was the complete learning of the interference habit during the very early stage of development. It did not seem advisable, moreover, to feed less frequently than twice a day, or to feed without running the animals.

The learning situation was similar to that of Experiment IV. The experimental animals, Series F, were given the following training: (*a*) complete learning of Maze 3, (*b*) rest three days (six practice periods), (*c*) complete relearning of Maze 3, (*d*) rest six practice periods, and (*e*) 40 trials in Maze 1. The control animals, both Series G and H, were given 40 trials in Maze 1 only. Each experimental animal and its control mates began training in Maze 1 in the same practice period.

Results

Learning the Interference. Rats at 20 days of age perform very differently in the maze from what is characteristic of older rats. General exploratory re-

[16]The order of running the different groups of animals was kept constant. Consequently, the time of running any animal did not vary more than a half hour from day to day.

actions are almost lacking. The most characteristic behavior is face-washing, turning around repeatedly in one place in the maze, and many very short ventures with retracing. The first one or two trials were consequently very tedious. The mazes, however, were well adapted to very young animals. The distances were short and the maze patterns were simple. The 31 experimental animals all completed the learning and relearning of Maze 3 by the thirty-fourth day of age. The distribution of the ages for completing this learning is shown below:

Age	27	28	29	30	31	32	33	34
Frequency	2	6	13	6	1			3

With the exception of three animals, all of Series F completed the interference learning at a very early age, i.e., by 31 days of age.

The results obtained from very young rats in learning Maze 3 were unusual. The real significance of the results for later learning in Maze 1 will appear most clearly in a comparison with the results from older experimental series. Table 32 shows the mean total scores for Series F and two series of older animals.[17]

[17]The differences between the three series are presented in the following table:

Series	Age	Distrib. practice	Food
F	20	2 trials a day	Whole milk, white bread, cod liver oil. Fed to satiety twice a day.
N	60	1 trial a day	Same as for F except once a day and not over ten minutes for eating.
D	51 (44-55)	1 trial a day	Skim-milk, white bread, cod liver oil. Time for eating, six minutes once a day. Additional quantitative stinting in beginning learning.

TABLE 32

MEAN TOTAL SCORES FOR DIFFERENT SERIES OF EXPERIMENTAL ANIMALS IN LEARNING AND RELEARNING MAZE 3

Series	Learning: Mean distance	Learning: Mean trials	Relearning: Mean distance	Relearning: Mean time
Series F	143.00	9.62	28.75	15.55
S.D.	65.87	2.89	14.91	10.78
Series N	61.00	6.07	27.21	14.43
S.D.	27.59	1.78	12.10	10.49
Series D	41.73	4.74	21.00	7.54
S.D.	19.62	1.47	0.00	1.65

The differences between F and N and between F and D are apparent in the mean total scores for first learning. In relearning there was no important difference between Series F and N. The magnitude of these differences and their standard errors are shown in Table 33. For mean distance and mean trial scores in first learning the differences are from five to eight times their standard errors. Since the only difference other than age between Series F and N was in distribution of practice, the comparison casts a strong presumption in favor of poorer learning ability in very young rats. This is in agreement with Liu's (65) findings in his study of the relation of age to maze-learning ability.

TABLE 33

DIFFERENCES BETWEEN THE MEAN TOTAL SCORES OF VERY YOUNG ANIMALS AND TWO SERIES OF OLDER ANIMALS INTERFERENCE-LEARNING, MAZE 3

Series	Learning: Distance	Learning: Trials	Relearning: Distance	Relearning: Time
F-N	82.00	3.55	1.54	1.12
$S.E._{m_1-m_2}$	13.94	0.70	4.20	3.41
F-D	101.27	4.88	7.75	8.01
$S.E._{m_1-m_2}$	12.58	0.58	2.68	1.96

He found that maze-learning ability in rats improved rapidly from 30 to 75 days of age. Results to be presented in this report will show that the difference between Series F and N in distribution of practice was probably of no importance in this connection. There was probably a significant difference between very young and older rats in learning ability.

Differences in Total Distance and Total Time Scores. The mean total scores for distance and time

TABLE 34
MEAN TOTAL SCORES AND STANDARD DEVIATIONS
MAZE 1

Trials	Distance Series F	Distance Series G	Distance Series H	Time Series F	Time Series G	Time Series H
1-4	90.16	116.20	96.67	115.38	217.08	174.05
S.D.	60.08	64.51	43.91	132.41	139.14	103.37
5-8	59.10	63.36	65.96	31.32	32.68	36.37
S.D.	22.63	18.82	24.15	27.27	15.36	21.55
9-12	54.19	57.00	62.64	23.92	23.04	27.26
S.D.	19.77	17.51	22.73	11.56	9.41	15.46
13-16	48.51	47.84	54.00	19.79	19.24	20.94
S.D.	17.17	11.72	13.78	11.37	10.86	8.03
17-20	46.90	50.08	48.21	18.43	17.63	18.82
S.D.	17.87	12.38	15.27	9.35	6.57	15.46
21-24	47.42	46.92	49.85	18.27	16.46	17.59
S.D.	15.38	13.80	12.42	8.95	6.68	7.14
25-28	39.10	45.35	49.00	14.87	15.18	16.95
S.D.	10.78	11.84	14.09	6.24	5.68	7.33
29-32	38.77	45.28	48.00	15.49	15.61	17.95
S.D.	15.32	12.35	12.32	8.73	3.97	8.37
33-36	39.16	44.88	43.92	14.15	16.83	15.33
S.D.	10.13	10.95	13.24	6.01	7.34	5.94
37-40	35.48	41.36	41.78	12.60	15.46	15.12
S.D.	8.17	9.71	10.36	5.80	5.69	5.96
25-40	152.51	176.88	182.71	57.12	63.10	65.35
S.D.	36.57	38.96	42.31	20.65	20.80	20.89
5-40	409.29	442.08	463.39	168.87	172.18	186.34
S.D.	92.54	86.84	79.34	58.73	40.98	54.42
1-40	498.80	558.28	560.07	284.25	389.27	360.40
S.D.	127.29	115.90	95.68	158.01	128.93	121.55

for different divisions of trials were determined in the same manner as in other experiments. These means and the standard deviations of the distributions of total scores are presented in Table 34. The most important fact in this table is the complete reversal of the direction of the transfer from what was obtained in experiments with older animals. Series G, the learning-control group, did catch up with Series F in Trals 12-16, but Series F improved more rapidly in later trials than either of the control series in both distance and time scores. The larger divisions of trials also show that Series F had the advantage. The differences between Series F and G in the means of the total distance and total time scores and the standard errors of these differences are presented in Table 35. The differences are all in the same direction for the later divisions of trials and for Trials 5-40, but they are not quite statistically significant. That positive transfer, nevertheless, was more effective than any negative transfer that might have developed seems conclusive.

TABLE 35
DIFFERENCES BETWEEN THE MEANS AND THE STANDARD ERRORS OF THE DIFFERENCES
MAZE 1

	F-G*			
	Distance		Time	
Trials	Difference	$S.E._{m_1-m_2}$	Difference	$S.E._{m_1-m_2}$
33-36	— 5.72	2.78	—1.33	1.82
37-40	— 5.88	2.43	—2.86	1.54
25-40	—24.37	10.19	—5.98	5.57
5-40	—32.79	24.04	—3.31	13.36

*Series F were the experimental animals and Series G were the control animals.

The means in Table 34 indicate slightly poorer learning in six out of ten levels of practice for Series H than for Series G. The differences are not statistically significant in view of the size of the standard deviations. What may have been the causes of these slight differences is not clear. There was no difference in feeding after weaning, and no difference in practice procedure. The absence of any significant difference between Series G and H indicates that the early weaning and the diet and feeding probably did not affect the normal development of the learning ability of the animals in Series F and G.

Differences in Response Patterns. The fact that no evidence of negative transfer was apparent in the differences between the experimental and control animals in the mean total scores for distance and time is not proof that it was not present. The fact that the differences indicating positive transfer were not quite significant indicates that some negative transfer may have been present. The analysis of performance throws some light on this problem.

Performance was recorded graphically as in the case of older rats in other experiments. An examination of these records revealed no new response patterns, and no need for a different classification of responses. Two methods of treating the data on response patterns were employed. (*a*) The percentage of trials for each response pattern for the different levels of practice was ascertained. (*b*) The mean number of certain response patterns per animal was computed for different divisions of trials.

The results by the first method are presented in Tables 36, 37, and 38. A comparison of the percentages of *a*- and *b*-responses for Series F and G shows that negative transfer was present. The percentages of both of these patterns were considerably higher than for either of the control series. But, as compared with older experimental animals, the percentages for Series F are similar only in the first eight trials. In Trials

TABLE 36
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES F ON MAZE 1

Trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	62.9	8.1	14.5	6.4	1.6	6.4
5-8	41.9	9.7	1.6	17.7	4.8	24.2
9-12	34.7	7.3	0.8	17.7	10.5	29.0
13-16	31.4	6.4	0.0	12.1	14.5	35.5
17-20	18.5	3.2	3.2	9.7	24.2	41.1
21-24	17.7	4.0	0.0	13.7	27.4	37.1
25-28	21.0	1.6	0.0	4.0	23.4	50.0
29-32	15.3	4.8	0.0	4.8	14.5	60.5
33-36	29.8	0.8	0.0	4.0	19.4	46.0
37-40	20.2	0.8	0.0	1.6	17.7	59.7
1-40	29.35	4.67	2.01	9.19	15.80	38.94

TABLE 37
PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN
SERIES G ON MAZE 1

Trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	32.0	5.0	28.0	18.0	7.0	10.0
5-8	16.0	6.0	4.0	17.0	37.0	20.0
9-12	11.0	5.0	1.0	19.0	46.0	18.0
13-16	4.0	1.0	0.0	10.0	59.0	26.0
17-20	5.0	1.0	0.0	15.0	58.0	21.0
21-24	2.0	0.0	0.0	10.0	62.0	26.0
25-28	3.0	0.0	0.0	7.0	60.0	30.0
29-32	4.0	0.0	0.0	5.0	62.0	29.0
33-36	11.0	1.0	0.0	6.0	55.0	27.0
37-40	7.0	0.0	0.0	5.0	47.0	41.0
1-40	9.5	1.9	3.3	11.2	49.3	24.8

TABLE 38

PERCENTAGE OF TRIALS FOR EACH RESPONSE PATTERN SERIES H ON MAZE 1

Trials	Response patterns *a*	*b*	*f*	*c*	*d*	*p*
1-4	41.1	8.0	20.5	9.8	2.7	17.9
5-8	11.6	4.5	4.5	30.3	22.3	26.8
9-12	8.0	3.6	2.7	24.1	40.2	21.4
13-16	12.5	0.9	0.0	16.9	49.1	20.5
17-20	9.8	0.9	0.9	9.8	51.9	26.8
21-24	5.3	0.0	0.0	16.1	54.5	24.1
25-28	6.2	2.7	0.0	15.2	49.1	26.8
29-32	5.3	0.0	0.0	21.4	43.7	29.5
33-36	8.0	0.0	0.0	10.7	42.8	38.4
37-40	10.7	0.0	0.0	6.2	42.8	40.2
1-40	11.87	2.05	2.85	16.07	39.90	27.23

TABLE 39

PERCENTAGE OF TRIALS FOR RESPONSE PATTERN *a* FOR DIFFERENT DIVISIONS OF TRIALS AND DIFFERENT SERIES OF ANIMALS

Trials	Series of experimental animals* F	N	D	A	B
1-4	62.9	80.3	84.6	67.7	55.4
5-8	41.9	57.1	55.1	63.6	50.9
9-12	34.7	55.3	49.2	60.3	38.4
13-16	31.4	62.5	45.6	54.2	49.1
17-20	18.5	57.1	44.1	50.0	53.0
21-24	17.7	64.3	43.4	49.0	34.8
25-28	21.0	58.9	37.5	44.8	35.7
29-32	15.3	60.7	38.2	44.8	41.1
33-36	29.8	58.9	42.6	41.6	42.9
37-40	20.2	51.8	45.6	39.6	44.6
1-40	29.35	60.51	48.6	51.6	42.6

*The full results for Series A and B were reported in Chapter III, for Series D in Chapter IV. Series N has been described in this chapter.

17-40 the percentages of *a*-responses are approximately only one-third to one-half as large as for other experimental groups. This is shown in Table 39. As compared with older animals, the interference in very young animals broke down rapidly after the first 16 trials. It was very probably this marked decrease in

percentages of *a*-responses that produced a difference in distance scores in favor of positive transfer.

The question might be raised: were the differences in performance between the control and experimental animals significant? This is developed in the treatment of response patterns by the second method. The mean number of *a*- and *dp*-response-patterns for different divisions of trials is shown in Tables 40 and 41. The differences between Series F and G are significant for both *a*- and *dp*-patterns. The negative transfer of the food-direction habit acquired in learning Maze 3

TABLE 40
MEAN NUMBER OF RESPONSE PATTERNS PER ANIMAL
MAZE 1

Trials	Pattern *a* Series F*	Series G	Series H	Patterns *dp* Series F	Series G	Series H
1-20	7.51	2.72	3.42	7.71	12.08	11.17
S.D.	5.89	2.52	3.64	4.88	4.56	5.44
21-40	4.13	1.12	1.42	14.22	17.52	15.67
S.D.	5.72	1.39	2.81	6.19	4.06	5.06
1-40	11.64	3.84	4.85	21.93	29.60	26.85
S.D.	9.92	3.27	5.26	9.89	7.65	9.14

*The experimental animals were Series F. The control animals were Series G and H. G was the learning control.

TABLE 41
DIFFERENCES BETWEEN SERIES F AND G IN THE MEAN NUMBER OF RESPONSE PATTERNS
MAZE 1

Trials	Pattern *a* Difference	$S.E._{m_1-m_2}$	Patterns *dp* *Difference*	$S.E._{m_1-m_2}$
1-20	4.79	1.17	—4.37	1.26
21-40	3.01	1.06	—3.30	1.38
1-40	7.80	1.90	—7.67	2.28

TABLE 42

MEAN NUMBER OF RESPONSE PATTERNS *d* AND *p* PER ANIMAL
MAZE 1

Trials	Pattern *d* Series F	Pattern *d* Series G	Pattern *p* Series F	Pattern *p* Series G
1-40	6.35	19.72	15.58	9.88
S.D.	7.19	11.45	9.93	9.31

TABLE 43

DIFFERENCES BETWEEN SERIES F AND G IN THE MEAN NUMBER OF RESPONSE PATTERNS

Trials	Pattern *d* Difference	Pattern *d* $S.E._{m_1-m_2}$	Pattern *p* Difference	Pattern *p* $S.E._{m_1-m_2}$
1-40	−13.37	2.62	5.70	2.58

did interfere significantly with learning the new direction of food. Tables 42 and 43 indicate that positive transfer was also present. The difference between Series F and G in the mean number of *d*-responses is negative and five times its standard error. The experimental animals did not enter the first blind alley to the right side of the maze as frequently as control animals. They had been negatively adapted to that alley in learning Maze 3. The low percentages of responses *a* and *d* as determined by the influence of previous learning necessarily meant higher percentages of other patterns, including perfect responses. The data show that the increase was in percentages of perfect responses which meant positive transfer.

The real significance of the data on negative transfer in young rats depends somewhat upon the comparability of these data with similar data from older animals. In learning Maze 3, the very young showed

much poorer learning than older animals. In one comparison the only important difference in procedure was the difference in distribution of practice. The question is: did this difference in distribution of practice account for the difference in learning? This can be answered rather conclusively. The same difference in distribution of practice was observed in learning Maze 1. The results from this second learning should throw some light on the influence of the difference in distribution of practice. The mean total scores for different series of animals in learning Maze 1 are shown in Table 44. Series O (14 animals) was the control group for Series N. The other series were described in the first part of this chapter. The most important comparisons are between Series F and N and between Series G and O. In Trials 25-40, the two control groups show almost no differences either in mean distance or mean time scores. For the same division of

TABLE 44
MEAN TOTAL SCORES FOR DIFFERENT SERIES OF ANIMALS
MAZE 1

	Experimental			Control		
Trials	F*	N	D	G*	O	E
			Distance Scores			
25-40	152.51	178.71	192.61	176.88	175.57	152.88
S.D.	36.57	32.46	51.55	38.96	35.14	31.12
5-40	409.29	422.85	470.08	442.08	474.07	421.81
S.D.	92.54	59.38	108.66	86.84	66.53	81.67
			Time Scores (Seconds)			
25-40	57.12	59.00	68.96	63.10	63.12	52.93
S.D.	20.65	13.46	22.74	20.80	14.29	13.41
5-40	168.87	150.01	191.32	172.18	209.89	165.48
S.D.	58.74	38.86	58.56	40.98	55.79	40.02

*Series G, O, and E were the control groups for Series F, N, and D, respectively.

trials, the experimental animals, on the contrary, show just the reverse of the differences obtained in learning Maze 3. The very young experimental animals show better learning. The difference between F and D is even more pronounced. The significance of these differences is shown in Table 45. There were no significant differences between the controls of very young rats and the controls of older animals. In Trials 25-40 some of the differences between very young experimental animals and older experimental animals are significant, but for Trials 5-40 none of the differences is significant. These data show no difference in learning due to difference in distribution of practice. There were no significant differences between comparable control series. Moreover, seven differences out of eight indicated better learning in very young experimental animals than occurred in older experimental animals. In view of this latter fact, it should be re-

TABLE 45

DIFFERENCES BETWEEN THE MEAN TOTAL SCORES OF VERY YOUNG RATS AND TWO SERIES OF OLDER RATS

MAZE 1

Trials	Experimental animals F-N	F-D	Control animals G-O	G-E
		Distance		
25-40	—27.20	—40.10	1.31	24.00
S.E.	10.88	11.02	12.19	9.88
5-40	—13.56	—60.79	—31.99*	20.27
S.E.	22.08	24.97	21.57	23.72
		Time (Seconds)		
25-40	—1.88	—11.84	— 0.02	10.17
S.E.	5.16	5.38	5.64	4.90
5-40	18.56	—22.45	—37.71*	6.70
S.E.	14.80	14.56	17.02	11.25

*Large differences here were due to two very large scores in Trials 4-8.

called here that negative transfer was much more pronounced in all series of older experimental animals. That, and not the difference in distribution of practice, probably accounts for better learning by very young experimental animals in Maze 1.

SUMMARY

1. Three series of very young male rats were made up of littermates selected for nearest like weight. The experimental animals and the learning control were weaned at 18 days of age. The growth-control animals were weaned at 28 to 30 days of age. All control litters for Series H, the growth-control group, were kept average in size.[18]

2. The learning procedure for Series F was as follows: (*a*) complete learning of Maze 3, beginning at 20 days of age, (*b*) rest three days, (*c*) complete relearning of Maze 3, (*d*) rest three days, and (*e*) 40 trials in Maze 1. The controls, Series G and H, were trained only in Maze 1. The distribution of practice was two trials a day, one in the morning and one in the evening.

3. Rats were successfully weaned at 18 days of age. They were fed white bread soaked in whole milk with cod liver oil. Their growth in weight was normal as compared with the growth of animals not weaned until 30 days of age. Food was left in the cages a half-hour on the first few days, then for five minutes after each

[18]The litters were increased in number to six, seven, or eight by supplying rats from other litters. Usually these made-up litters were six or seven, but never less, and never above eight.

practice period in Maze 1. The animals were fed to satiation.

4. The results from the learning in Maze 3 by Series F show (*a*) that rats can begin learning a simple maze at 20 days of age, using food for incentive, and (*b*) that, by all criteria, the very young rats with two trials a day showed much poorer learning than older animals with one trial a day. The differences were all significant.

5. In learning Maze 1 the mean total distance scores and the mean total time scores indicate (*a*) positive transfer as a result of previous learning in Maze 3 and (*b*) no significant differences between the learning-control and the growth-control groups.

6. The analysis of performance indicates that both positive and negative transfer were probably present. The precentages of the interfering pattern, response *a*, were considerably higher for the experimental animals than for either control group. The food-direction habit acquired in learning Maze 3 did interfere significantly with learning the new direction of food in Maze 1. Positive transfer appeared in the form of lower percentages of response *d* but larger percentages of perfect responses than for the control series.

7. In the percentages of *a*-responses a comparison of very young experimental animals with four series of older experimental animals indicated (*a*) that in Trials 1-8 the percentages were similarly high for all series, and (*b*) that in Trials 17-40 the percentages for very young rats were only one-third to one-half as high as for older animals. This break-down of the inter-

fering response patterns in very young animals, their large percentages of *b*-responses, and their poorer learning in Maze 3, all suggest poorer integration of response patterns in very young rats than in older animals. If this integration consists of postural units which are set off by initial cues in the learning situation and which, by shorter or longer leaps, precede explicit performance, then age differences in learning and interference may be explained. Learning was poorer in the early stages of immaturity and rapid development because (*a*) the postural units were shorter, less inclusive, and (*b*) the fixation of response patterns was more difficult. The interference in very young animals was less pronounced and less likely to persist than in older animals (*a*) because the postural units constituting the integration of the response patterns were shorter, and (b) because the fixation of the interfering response patterns deteriorated more rapidly under the conditions of much more rapid muscular and neural development.

8. The poorer learning of very young rats in Maze 3 was probably due to poorer learning ability. In learning Maze 1 with the same difference in distribution of practice there were no significant differences between the very young control animals and comparable series of much older control animals.

VI

NEGATIVE TRANSFER BETWEEN MAZES OF SIMILAR DIFFICULTY

In the experiments with Mazes 2 and 4 and Mazes 3 and 1 the experimental animals learned a very easy maze first and then a much more difficult maze. The plan of the investigation was to control this factor, difference in difficulty, by experiments with easy mazes of similar difficulty. The necessity for such experiments became especially urgent when the results from the experiments with very young rats indicated a rapid break-down in negative transfer after the first 16 trials in Maze 1. It seemed possible that if the second maze

TABLE 46

THE MAIN FACTS ABOUT THE ANIMALS IN EXPERIMENTS WITH SIMILAR MAZES

Experiment	Series	Sex	Age	N	Methods of grouping	Diet: Time per day (minutes)	Diet: Composition
V	I	F	20	25	Littermates of nearest like weight	60-10	White bread one pound; whole milk one quart; and cod liver oil, one dessert-spoonful
	J (control)	F	20	25			
VI	K	F	30	23	No control group	10	
VII	L	M	75	20	Littermates of nearest like weight	10	White bread, one pound; whole milk, one pint; skim-milk one pint; and cod liver oil, one dessert-spoonful
	M (control)	M	75	21			

TABLE 47

MAIN FACTS ABOUT THE PROCEDURE IN EXPERIMENTS WITH SIMILAR MAZES

Experiment	Series	Mazes Habit 1	Mazes Habit 2	Criterion of learning No. perf. trials Habit 1	Criterion of learning No. perf. trials Habit 2	Trials each day	Practice procedure
V	I	3*a*	1*a*	3	6	2	M 3*a*—rest 3 days—Re. M 3*a*—rest 3 days—M 1*a*—rest 6 days—Re. M 1*a**
	J (control)		1*a*				M 1*a*—rest 6 days—Re. M 1*a*
VI	K	3*a*	1*a*	6	6	1	M 3*a*—rest 3 days—M 1*a*
VII	L	3*a*	1*a*	3	6	1	M 3*a*—rest 3 days—Re. M 3*a*—rest 3 days—M 1*a*—rest 6 days—Re. M 1*a*—rest 40 days—Re. M 1*a*
	M (control)		1*a*				M 1*a*—rest 6 days—Re. M 1*a*—rest 40 days—Re. M 1*a*

*M=Maze; Re. = relearning.

had been similar in difficulty to the first the outcome might have been negative transfer instead of positive. The marked changes in development of young animals and their rapid growth during the time of learning might have interfered with long continued retention of the interfering habit. In accord with this conjecture, three different experiments were undertaken as a check on the findings obtained in more difficult mazes.

PROCEDURE

The facts about the animals and procedure are shown in Tables 46 and 47. Series I and J were weaned at

18 days of age and the control animals began maze learning at 20 days of age. For these very young rats the time for eating was distributed as in Experiment IV. Thirty minutes following each practice period were allowed for eating for the first four or five days. This was reduced gradually to a five-minute period following each practice at the beginning of learning the second maze. This meant, for the most part, satiety. The distribution of practice for Series I and J was one trial in the morning between 7:30 and 10:00 o'clock and one in the evening between 7:00 o'clock and 9:30.[19] The relearning of Maze 1*a* after a rest of 6 days and again after another rest of 40 days was given as a test of the recurrence of interference. Mazes 3*a* and 1*a* were simplifications of Mazes 3 and 1, respectively.[20] The change consisted of closing the blind alley nearest to the entrance. Each maze then consisted of the main alley, one blind alley, and the true alley. In Maze 3*a* the true path led to the end of the box, as in Maze 3, but in Maze 1*a* the true path was the first alley to the right as in Maze 1.

Results

Experiment V

The results from this experiment with very young rats agreed, in the main, with the findings in Experiment IV. Maze 3*a* was easily learned. The mean total scores for Series I, the experimental animals, and

[19]The order of running the groups of animals was kept constant. The time for running any one animal would, therfore, not vary over a half-hour from day to day.

[20]See Table 3 and Figures 1 and 2 in Chapter II.

TABLE 48
MEAN TOTAL SCORES
SERIES I ON MAZE 3a

	Distance	Time	Trials
Learning	106.24	478.61	6.76
S.D.	33.02	306.60	1.68
Relearning	37.08	22.54	4.36
S.D.	29.91	18.52	2.46

the standard deviations of the total scores for learning and relearning are shown in Table 48. The mean total scores for relearning indicate that retention was not perfect. The time scores for first learning are large as one should expect for very young animals. The results from learning Maze 1*a* are presented in Table 49. The mean total scores for distance and time in first learning are for trials three to complete learning. For trial scores in learning and for all criteria in relearning the mean total scores are for total trials. The first two trials were not included for mean total distance scores and mean total time scores because the experimental and control animals in these trials were not comparable. Series J had had no previous maze ex-

TABLE 49
MEAN TOTAL SCORES FOR LEARNING AND RELEARNING AND STANDARD DEVIATIONS OF TOTAL SCORES
MAZE 1a

	Learning			Relearning		
Series	Distance	Time	Trials	Distance	Time	Trials
I	142.56	54.32	16.16	58.40	23.74	7.48
S.D.	200.28	71.38	15.81	56.18	27.46	5.73
J*	77.92	44.68	10.56	46.12	18.34	6.44
S.D.	46.81	35.50	3.54	16.00	12.36	2.16

**J was the control series.*

TABLE 50
DIFFERENCES BETWEEN THE MEANS OF TOTAL SCORES
MAZE 1*a*

	Distance	Time	Trials
I-J	64.64	9.64	5.60
$S.E._{m_1-m_2}$	41.14	15.94	3.24

perience. It was not the purpose of this study to measure general practice effects or temporary disturbance from previous maze experience.

At first sight one might infer from the differences between Series I and J that there was considerable negative transfer. This appears in all three criteria. But these differences are not significant. This is shown clearly in Table 50. They are small in comparison with their standard errors. But it is very possible that they represent, nevertheless, a slight degree of negative transfer, inasmuch as one ordinarily should expect considerable positive transfer from previous maze learning. The experimental animals also showed slightly poorer retention in the relearning of Maze 1*a*. The differences between it and Series J, however, are clearly not significant.[21]

The results from this experiment agree in the main with the results obtained from very young rats in learning Maze 1. There is some evidence that negative transfer was present in both learning situations. But

[21]No analysis of responses was made. After the first two or three trials there were only two different responses. Every error resulted in a corresponding increase in time and distance. Consequently, there were probably no important differences in performance not revealed in distance and time scores.

in learning Maze 1, the difficult maze, the interference broke down before the control animals could make sufficient gains to produce a negative difference. In this experiment with easy mazes the controls gained so rapidly that a negative difference was produced before the interference gave way. But in both experiments the differences between the experimental and control animals in mean total distance and time scores showed no significant transfer effects. They were both instances of only slight differences between the effects of positive and negative transfer.

Experiment VI

Since no control group was used in this experiment and since Mazes 3*a* and 1*a* were not necessarily equal in difficulty, the results of this experiment are presented with the results from the control groups of Experiments

TABLE 51

MEAN TOTAL SCORES FOR DIFFERENT SERIES OF ANIMALS

Maze	Distance (3-c)*	Time (3-c)	Trials
	Series K		
3*a*	91.65	66.07	11.87
S.D.	54.76	41.55	4.52
1*a*	157.74	66.44	17.60
S.D.	121.17	54.34	9.66
	Series J		
1*a*	77.92	44.68	10.56
S.D.	46.81	35.50	3.54
	Series M		
1*a*	76.52†	41.42	11.19
S.D.	73.07	31.95	6.83

*Distance and time scores did not include the first two trials.
†This mean is 23.52 higher than the median due to position habits in two animals the sum of whose scores was 589, or 483 above the sum of two median scores. All means for Series M are correspondingly high.

V and VII. The mean total scores and standard deviations for Series K, J, and M are shown in Table 51. It will be seen in this table that all comparisons except one indicate considerable negative transfer in Series K. The one comparison not indicating negative transfer is the comparison between the mean total time scores for Mazes 3*a* and 1*a* for Series K. The control series, J and M, both made slightly lower mean total scores in learning Maze 1*a* than Series K made in learning Maze 3*a*. In view of this fact, it seems unlikely that Maze 1*a* was any more difficult than Maze 3*a*.

The differences showing the effects of transfer and the standard errors of these differences are given in Table 52. The differences between Mazes 1*a* and 3*a* for Series K, K and J for Maze 1*a*, and K and M for Maze 1*a*, all indicate some negative transfer. Of the

TABLE 52

DIFFERENCES BETWEEN THE MEANS OF TOTAL SCORES FOR DIFFERENT SERIES

*Difference**	*Distance*	*Time*	*Trials*
K_{1_a}-K_{3_a}	66.09	0.37	5.73
$S.E._{m_1-m_2}$	26.78	14.25	2.32
K_{1_a}-J_{1_a}	79.82	21.76	7.04
$S.E._{m_1-m_2}$	26.92	13.36	2.13
K_{1_a}-M_{1_a}	81.22	25.02	6.41
$S.E._{m_1-m_2}$	29.84	13.29	2.50
K_{3_a}-J_{1_a}	13.73	21.39	1.31
$S.E._{m_1-m_2}$	14.76	11.20	1.18
K_{3_a}-M_{1_a}	15.13	24.65	0.68
$S.E._{m_1-m_2}$	19.59	11.11	1.76

*The subscripts indicate the mazes in which the learning took place.

nine differences obtained in this manner, six are from two and one-half to more than three times their standard errors. From these data it seems clear that negative transfer was more effective when the interference habit was developed after 30 days of age than when it was acquired immediately after 20 days of age. There was no evidence in the results from either of the foregoing experiments that the interference between Maze 3 and Maze 1 in previous experiments was due to the difference in difficulty of the two mazes. On the contrary, it seems that interference in very young rats is more likely to appear in the form of a difference between mean total distance, or time, scores when the mazes are both easy and of similar difficulty.

Experiment VII

The results from interference learning at 75 days of age should be especially important. Liu (65) found that white rats at that age were at the peak of learning ability. The evaluation of interference in learning

TABLE 53

MEAN TOTAL SCORES, STANDARD DEVIATIONS OF TOTAL SCORES, DIFFERENCES BETWEEN THE MEAN TOTAL SCORES OF TWO SERIES OF EXPERIMENTAL ANIMALS, AND THE STANDARD ERRORS OF THE DIFFERENCES BETWEEN THE MEANS—LEARNING AND RELEARNING MAZE 3*a*

Series	Learning Distance	Learning Time	Learning Trials	Relearning Distance	Relearning Time	Relearning Trials
L	64.75	128.53	6.35	22.35	10.02	3.15
S.D.	30.50	71.00	2.46	5.88	10.24	0.65
I	106.24	478.63	6.76	37.08	22.54	4.36
S.D.	33.02	306.60	1.68	29.91	18.52	2.46
I-L	41.49	350.10	0.41	14.73	12.52	1.21
$S.E._{m_1-m_2}$	9.60	70.04	0.62	6.79	4.62	0.57

TABLE 54

MEAN TOTAL SCORES, STANDARD DEVIATIONS OF TOTAL SCORES, DIFFERENCES BETWEEN THE MEAN TOTAL SCORES FOR SERIES *L* AND M AND THE STANDARD ERRORS OF THE DIFFERENCES

MAZE 1*a*

Series	*Distance*	*Time*	*Trials*
L	365.70	117.67	32.35
S.D.	424.80	131.34	31.22
M	76.52	41.42	11.19
S.D.	73.07	31.95	6.83
L-M	293.34	76.76	21.16
$S.E._{m_1-m_2}$	96.32	30.18	7.14

Maze 1*a* requires, therefore, a comparison at this point between the learning of Series I and L. The main facts for this comparison will be found in Table 53. In both learning and relearning, the differences between Series I and L are considerable. The differences between the means and their standard errors are shown in the last two lines. Series I and L are not *comparable in mean total time scores. The very young rat is physically incapable of speed comparable with that of older rats in running through the maze.* With the exception of mean total trials in first learning, all the differences are nearly significant. These differences agree with the results from very young rats in difficult mazes. Significant differences were found in Experiment IV between series of very young and much older animals.

The influence of the better learning in Maze 3*a* by older animals is evident in the results from Maze 1*a*. The essential facts are shown in Table 54. The mean total distance and time scores are for complete learning, or 80 trials (in case learning was not completed

earlier) minus the first two trials.[22] The differences are, in the main, significant. The standard errors were high because of the bimodal distributions. Some animals seem to be immune to interference. Their learning scores are very low. In other animals the interference persists over many trials making complete learning by the trial-and-error method all but impossible. The result is a bimodal distribution with large standard deviations for total scores and, therefore, large standard errors. This bimodal tendency is not evident in the total scores of very young animals. They are clearly less subject to persistent fixation of the interfering habit. This confirms the findings with more difficult mazes. The interfering responses in very young animals gave way rapidly after the first 8 trials, whereas in older animals the interference showed little depreciation at the end of 40 trials.

In view of the persistence of interference in older animals two relearning tests of Maze 1*a* were given: one after six days rest and the other forty days after completing the first test. The object of these tests was to investigate the recurrence of interference. The fact that several experimental animals failed to learn Maze 1*a* in 8 trials complicated this investigation. At 80 trials, their regular training was stopped and a guidance procedure was adopted for them. The blind alley (at the end of the problem box), which they had been running with dogged persistence, was blocked once (beginning with the eighty-first trial) after every two consecutive trials with error. In blocking, the

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[22]Six animals had not completed learning by the eightieth trial.

TABLE 55

MEAN TOTAL SCORES FOR CONDITIONED LEARNING SERIES L ON MAZE Ia

	Distance	Time	Trials
Conditioned trials	31.50	10.63	4.50
S.D.	17.02	5.89	2.43
Unconditioned trials	149.00	44.80	15.33
S.D.	68.00	22.73	5.41

entrance to this alley was left slightly open so that the similarity with the conditions of other trials was not disrupted. This procedure meant that for every two consecutive trials with error the animals were forced to make one perfect run or retrace the main alley. In no case did they retrace. The results from this procedure for gradual conditioning are presented in Table 55. The conditioned trials were the trials with the blind alley blocked. The unconditioned trials were those without maze blocking. The mean total scores by these two methods of measuring conditioned learning and the standard deviations indicate that the animals (six in number) were not of equal learning ability. The distributions of trial scores were 4, 6, 2, 1, 6, and 8 for conditioned trials and 16, 22, 10, 17, 16, and 21, respectively, for the unconditioned trials. This means that one animal required only one forced perfect trial to break up the interference, and the largest number of such trials for any one animal was eight. By this method every animal overcame the interference and satisfied the criterion of perfect learning.

These conditioned animals were then given the relearning tests in the same manner as the unconditioned animals. The results for all animals from the two

TABLE 56

MEAN TOTAL SCORES FOR RELEARNING IN SIX DAYS AFTER FIRST LEARNING AND AGAIN FORTY DAYS AFTER FIRST RELEARNING

MAZE 1*a*

Series	Relearning after 6 days Distance	Time	Trials	Relearning after 40 days Distance	Time	Trials
L	43.00	13.96	6.10	42.00	15.05	6.00
S.D.	4.58	5.09	0.43	0.00	2.59	0.00
M*	48.30	16.96	6.60	47.95	18.18	6.35
S.D.	13.68	6.44	1.28	13.42	7.70	0.96
L-M	—5.30	— 3.00	—0.50	— 5.95	— 3.13	—0.35
$S.E._{m_1-m_2}$	3.54	1.37	0.30	2.93	1.78	0.21

*The control animals were Series M.

relearning tests are shown in Table 56. There were no significant differences in either relearning test. But every difference for both tests favored better retention of the second maze habit in the experimental animals than in the controls. This result obviously means that there was no recurrence of the interference in the relearning tests. But it probably means much more than that. The greater recency of the second food-direction habit, and the overlearning of it in the first relearning test, might account for the better retention in experimental animals. It must be recalled, however, that several of the experimental animals had persisted in the interfering habit over a long succession of trials. If frequency was an important factor, the experimental animals should have been disturbed considerably in the relearning tests. This was not the case. The reorganized habit, the new response pattern, acquired in learning Maze 1*a* persisted in spite of the long practice of the interfering response pattern. In learning Maze 1*a* the interference must have been

due to the transfer of a whole response system, a response pattern, and not to the transfer of identical elements. Consequently, the new response pattern acquired in Maze 1*a* suffered no disruption.

SUMMARY

1. Three experiments were conducted to test interference between easy mazes of similar difficulty. Five series of animals (114 in all) were used. The ages at the time of beginning the first maze were 20 days, 30 days, and 75 days. The mazes were 3*a* and 1*a*, both of which were very simple mazes with only one blind alley in each. In difficulty they would compare with the T-shaped discrimination box used as a maze.

2. The learning of rats at 75 days of age was significantly better than the learning of rats beginning at 20 days. The results agree with Liu's findings.

3. The mean total distance and time scores for very young experimental and control animals indicated some negative transfer. But none of the differences were statistically significant. The results from this experiment agreed with the results from experiments with very young rats and difficult mazes. The differences between experimental and control animals in mean total distance and time scores showed no significant transfer effects, that is, the differences between the effect of positive and negative transfer were not significant.

4. The differences between the control animals and the experimental animals in mean total distance and time scores, and the standard errors of the differences, indicate that negative transfer effects increased as the

age of the animals at the time of learning the interfering maze habit increased. The persistence of the interfering response pattern increased conspicuously as the age of the animals at the time of acquiring the interfering pattern increased. Moreover, since both maze-learning ability and the persistence of interference increased with age, it appears, so far as groups are concerned, that the better the maze-learning ability in the first maze the greater the interference in the second maze.

5. There was probably slight difference, if any, in difficulty between Maze 3*a* and Maze 1*a*.

6. Such data as were obtained indicate that habit interference in terms of the differences between experimental and control groups in the mean total distance, or time, scores is more likely to appear in very young rats when both mazes are easy and similar in difficulty than when the second maze is difficult.

7. In these experiments as in previous experiments some animals show no negative transfer effects.

8. The relearning tests, one 6 days after completing the learning of Maze 1*a* and the other 40 days after completing the first test, gave no indication of the recurrence of interference. Every difference that obtained between the experimental and control animals indicated better retention in the experimental animals.

9. Interfering response patterns persisting for 80 trials were overcome by a method of gradual conditioning in which the animals were forced, by blocking the blind alley, to run one perfect trial after every two consecutive trials with error.

10. Negative transfer is probably due in part to identical elements, or cues, in the external situations, but it does not seem to consist of the transfer of response elements, but rather of the transfer of response patterns themselves.

VII

THE RELATION OF NEGATIVE TRANSFER TO VARIABILITY

Considerable evidence of relationship between negative transfer and variability has already been presented in this report. There has been evidence of the absence of negative transfer in some animals and the marked persistence of it in others. The standard deviations of total scores for response patterns, distance, time and trials have indicated higher absolute variability for experimental animals than for control animals. There has been evidence of bimodality in the distributions of distance and trial scores for experimental animals. Moreover, under the conditions of negative transfer, retarded learning, except in very young rats, has been the usual outcome. It is the purpose of this chapter to determine, as far as possible, from the data already presented and from further experimentation what might have been the relationship between negative transfer and variability in these experiments.

Variability in Learning Easy Mazes

The data from Experiments V, VI, and VII, which were presented in Chapter VI, have a very direct bearing on this problem. The standard deviations for total distance, total time, and total trial scores for the experimental and control animals are presented in Table 57. Every one of the nine comparisons given in this table indicates much higher variability for learning under the conditions of previous interference

TABLE 57

STANDARD DEVIATIONS FOR TOTAL SCORES FROM EXPERIMENTS WITH EASY MAZES OF SIMILAR DIFFICULTY

Series*	Age	N	Distance†	Time	Trials
I_{1a}	20	25	200.28	71.38	15.81
J_{1a}	20	25	46.81	35.50	3.54
K_{1a}	30	23	121.17	54.34	9.66
K_{3a}	30		54.76	41.55	4.52
L_{1a}	75	20	424.80	131.34	31.22
M_{1a}	75	21	73.07	31.95	6.83
L_{cond} ‡	75	20	68.00	22.73	5.41

*The controls are boldfaced. The subscripts denote the mazes in which learning took place.

†For distance and time the first two trials are excluded as noted in Chapter VI.

‡These data are for the unconditioned trials in conditioned learning (see page 491).

learning. The standard deviations for the experimental series are higher for all criteria. It should be noted that Series K in learning Maze 3*a* had total scores with standard deviations much lower than those for total scores in learning Maze 1*a*. The transfer from learning in Maze 3*a* increased the variability considerably even in total time scores. Moreover, the standard deviations for Series L in conditioned learning are approximately the same as for the controls in learning without conditioning. Forced perfect trials counteracted the interference with the result that learning was approximately normal both in means and variability.

These data on variability, as they stand, do not show that negative transfer alone was the cause of higher variability in experimental animals. Positive transfer

may have had a part. Marked positive transfer for all animals, however, would tend to telescope the distribution and reduce the discrimination. Animals making large scores in learning the first maze would probably show a much higher percentage of gain in learning the second maze than animals making small scores in first learning. The cause of this consists in the fact that the possibilities for improvement are limited by the maze situation.

Experiment VIII

The differences in variability between experimental and control animals in learning easy mazes of similar difficulty suggested a very much needed experiment. In the experiments with transfer from easy to difficult learning, the practice in learning the second maze was usually limited to 40 trials. To determine the full influence of negative transfer upon variability it seemed necessary to continue the trials to complete learning. The rate of learning by the controls after 40 trials and the persistence of interference in the experimental animals were not known.

Procedure. In Experiment VIII, 28 male rats were divided into two series of littermates paired for nearest like weight. They were fed to satiety (but not over ten minutes) once a day. The feed was practically the same as that used for very young rats.[23] This meant a considerably better diet than in any other experiment

[23]The feed was composed of white bread, whole and skim-milk, equal parts of each, and cod liver oil (1 dessertspoonful to each quart of milk).

with older rats.[24] At 60 days of age, Series N, the experimental animals, entered training in Maze 3. The rest of the learning procedure for this series consisted of (*a*) three days' rest after complete learning of Maze 3, (*b*) complete relearning of Maze 3, (*c*) rest three days, and (*d*) complete learning, or 108 trials, in Maze 1. The control mates, Series O, were given only the fourth step in the above procedure. In this last step all animals were given 40 trials. Then those that had satisfied the criterion, six perfect trials, were removed from further training. The remaining animals in the two series were continued in training until learning was complete, or to 108 trials. The distribution of practice was one trial a day.

Results. From the first 40 trials the results were, in the main, similar to those from experiments with animals of similar age. In Table 58 are presented the mean total scores and standard deviations of total scores for different divisions of trials. The absence of difference between the control and experimental animals in these mean total scores is not proof that negative transfer was not present. The analysis of performance indicates that for experimental animals it was present in a high degree. The facts are shown in Tables 59 and 60. The percentages of *a*-responses are very large for Series N as compared with Series O. These results agree, in the main, with the findings in other experiments with animals of similar age. This is shown in Table 61. The only important difference between Series N and D consists in a much smaller percentage

[24]Other groups of older animals were given six or eight minutes for eating, and no whole milk was used.

of *e*-responses. It will be seen also that there was a marked difference between Series N and Series F, the very young rats. The percentage of *a*-responses for Series N is twice as large as for Series F, but the percentage of perfect responses is only one-half as great as for Series F. There was, therefore, a substantial difference in performance between Series N and very young experimental animals. The performances of all control series, on the contrary, were essentially similar.

TABLE 58
MEAN TOTAL SCORES AND STANDARD DEVIATIONS
MAZE 1

	Distance		Time	
Trials	N	O	N	O
1-4	61.85	96.50	46.41	200.07
S.D.	17.11	35.94	20.56	71.58
5-8	51.85	92.85	22.04	68.66
S.D.	15.52	40.03	15.74	53.40
9-12	48.42	59.57	17.83	25.35
S.D.	9.66	10.09	6.58	6.64
13-16	49.00	51.14	17.45	17.52
S.D.	10.13	6.71	5.21	2.94
17-20	46.85	48.28	17.00	17.95
S.D.	10.85	9.18	6.57	2.55
21-24	47.00	46.57	16.68	17.27
S.D.	7.20	9.70	5.42	6.09
25-28	46.14	44.00	16.46	16.27
S.D.	5.88	10.00	4.95	4.30
29-32	45.85	43.71	15.67	15.70
S.D.	9.12	9.54	5.88	4.32
33-36	44.14	45.28	13.18	15.38
S.D.	8.73	8.53	2.81	3.49
37-40	43.57	42.57	13.67	15.75
S.D.	8.82	11.21	3.66	6.13
25-40	179.71	175.57	59.00	63.12
S.D.	32.47	35.14	13.46	14.29
5-40	422.85	474.07	150.01	209.89
S.D.	59.38	66.53	38.86	55.78
1-40	484.71	570.57	196.42	409.96
S.D.	53.56	82.75	41.72	118.53

TABLE 59

Percentages of Trials for Each Response Pattern Series N on Maze I

Trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	80.3	3.6	7.1	3.6	0.0	5.4
5-8	57.1	1.8	0.0	10.7	8.9	21.4
9-12	55.3	0.0	0.0	8.9	12.5	23.2
13-16	62.5	3.6	0.0	0.0	16.1	17.8
17-20	57.1	1.8	0.0	1.8	12.5	26.8
21-24	64.3	1.8	0.0	0.0	12.5	21.4
25-28	58.9	0.0	0.0	3.6	12.5	25.0
29-32	60.7	0.0	0.0	3.6	8.9	26.8
33-36	58.9	0.0	0.0	0.0	12.5	28.6
37-40	51.8	0.0	0.0	1.8	16.1	30.3
1-40	60.51	1.25	0.71	3.39	11.25	22.85

TABLE 60

Percentages of Trials for Each Response Pattern Series O on Maze I

Trials	Response patterns *a*	*b*	*f*	*e*	*d*	*p*
1-4	32.1	10.7	19.6	16.1	5.4	16.1
5-8	10.7	21.4	5.4	35.7	12.5	14.3
9-12	14.3	1.8	0.0	35.7	42.8	5.4
13-16	21.4	0.0	0.0	12.5	62.5	3.6
17-20	16.1	0.0	0.0	8.9	64.3	10.7
21-24	14.3	0.0	0.0	8.9	62.5	14.3
25-28	16.1	1.8	0.0	7.1	50.0	25.0
29-32	25.0	0.0	0.0	8.9	37.5	28.6
33-36	30.3	0.0	0.0	7.1	46.4	16.1
37-40	32.1	0.0	0.0	7.1	30.3	30.3
1-40	21.06	3.57	2.50	14.99	41.41	16.42

For the problem of this chapter the important thing in connection with these data is the fact that negative transfer in the form of large percentages of *a*-responses is present. The mean number of *a*- and *dp*-responses per animal for different divisions of trials is shown in Table 62. The significance of the differences between Series N and O in the mean number of response pat-

TABLE 61

PERCENTAGES OF TRIALS FOR EACH RESPONSE PATTERN FOR DIFFERENT SERIES OF ANIMALS, TRIALS 1-40

MAZE I

		Response patterns					
Series	Age*	*a*	*b*	*f*	*c*	*d*	*p*
				Experimental Animals			
N	60	60.51	1.25	0.71	3.39	11.25	22.85
D	51	48.60	1.00	1.80	13.10	16.90	18.60
F	20	29.35	4.67	2.01	9.19	15.80	38.94
				Control Animals			
O	60	21.06	3.57	2.50	14.99	41.41	16.42
E	51	15.10	0.90	1.60	12.90	40.70	28.80
G	20	9.50	1.90	3.30	11.20	49.30	24.80

*Age is always given for the time when the experimental animals begin Maze 3, the first maze.

TABLE 62

MEAN NUMBER OF RESPONSE PATTERNS PER ANIMAL AND THE STANDARD DEVIATIONS

MAZE I

	Pattern *a*		Patterns *dp*	
Trials	Series N	Series O	Series N	Series O
1-20	12.50	3.78	5.71	9.50
S.D.	7.69	3.43	6.09	4.55
21-40	11.71	4.71	7.85	13.64
S.D.	8.47	6.25	8.34	7.39
1-40	24.21	8.50	13.57	23.14
S.D.	16.06	8.80	13.94	11.65

TABLE 63

DIFFERENCES BETWEEN SERIES N AND SERIES O IN THE MEAN NUMBER OF RESPONSE PATTERNS

MAZE I

	Pattern *a*		Patterns *dp*	
Trials	Difference	$S.E._{m_1-m_2}$	Difference	$S.E._{m_1-m_2}$
1-20	8.72	2.25	—3.79	2.03
21-40	7.00	2.81	—5.79	2.98
1-40	15.71	4.90	—9.57	4.86

terns is presented in Table 63. These data indicate that negative transfer was present in a significant degree. It should be possible, therefore, from the results of the completed experiment, to test the relationship between negative transfer and relative variability.

The real significance of large percentages of *a*-response-patterns in this case hinges upon their effects on later learning. Training was continued to 108 trials for animals that had not completed learning. The mean total scores and standard deviations of total scores for Trials 5 to 108, or to complete learning if it was accomplished before the end of 108 trials, are presented in Table 64. The differences between Series N and O in mean total distance scores and mean total trials are considerable, but not significant because of the very large standard deviations, the small number of animals, and position habits in two control animals. But the important fact shown in this table is the much greater variability of the experimental animals. The differences between N and O in variability are probably greater than the differences between the standard deviations indicate. In learning Maze 1 the experimental animals started at a point considerably above

TABLE 64

MEAN TOTAL SCORES AND STANDARD DEVIATIONS FOR TRIALS 5-108 OR TO COMPLETE LEARNING

MAZE 1

Series	Distance	Time	Trials
N	861.57	288.25	74.94
S.D.	496.45	150.00	35.44
O	705.35	282.30	61.35
S.D.	308.55	108.90	23.06

zero. The previous maze experience transferred positively in beginning learning. It required in this, as in other similar experiments, approximately 16 trials for the control animals to offset their handicap from having had no previous experience. From zero or some common point of origin, the *achievement scores* for the experimental animals would be considerably lower than is represented by the distance (error) scores, time scores, and trial scores—as given. But there is no reason to believe that the standard deviations for the two series would, in that case, be relatively different from what they are in Table 64. The causes for the differences in variability between experimental and control animals are suggested in the distributions of total scores. These are presented in Table 66 for distance and trials. The class intervals are 100 and 8 for total distance and total trial scores, respectively, and the midpoints of the first intervals are 100 for distance and 20 for trials. The distributions for Series N are not only bimodal, but are greater in range than those for Series O. Better learning and poorer learning were characteristic of the experimental animals, as compared with the controls. After the sixty-fourth trial (sixth class interval) 50% or more of the experimental animals remained in training, whereas only 14 to 21% of the

TABLE 65

DISTRIBUTIONS OF TOTAL DISTANCE AND TOTAL TRIAL SCORES

Class Interval		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Distance	N	2	1		1	1	1			1			1	4	2
	O			1	1	4	1	2	2		1			1	1
Trials	N	1	2	1	1		1			1			7		
	O		1	1	1	4	2	1	1	1			2		

controls had not yet completed learning. The greater variability of the experimental animals was due largely to the fact that after the sixty-fourth trial the status of Series N for every level of practice to 108 trials was much poorer than for Series O. The greater variability of Series N seems to be due to both positive and negative transfer.

Variability of Total Scores for Different Levels of Practice in Difficult Mazes

The data on variability for different divisions of trials consist of coefficients of variation obtained through the use of derived mean total achievement scores. These achievement scores were calculated in the following manner. The mean total distance and mean total time scores for Trials 5-8, inclusive, for the control series in each experiment were selected as points of origin. The mean total achievement score for each division of trials for each series of animals was obtained by finding the difference between the mean total distance, or mean total time score, and the value of the point of origin. The scores thus obtained are distance and time reductions. The means for Trials 5-8 were selected as the points of origin because they were far less subject to marked fluctuations than the means for Trials 1-4. The coefficients of variability were computed by dividing the standard deviations of total distance and total time scores for different divisions of trials by the achievement scores. The coefficients of variability thus obtained are shown in Tables 66 to 69. Except in Series N and O, Trials 33-40 were not included because the number of perfect runs for the con-

trol animals in those trials would probably be large enough to reduce the variability of such groups. It should be recalled here (*a*) that Series D and E were highly motivated by food stinting, (*b*) that Series F and G were very young animals, (*c*) that Series N and O were small groups of well-fed animals similar in age to Series D and E, and (*d*) that Series B and C, the oldest animals, had no relearning of the interference before being transferred to Maze 4. It should be recalled also that in the experiment with Series F and G, very young animals, the interference broke down *rapidly after the sixteenth trial* with the result that the differences in mean total scores for Trials 25-40 showed positive transfer.

The coefficients, as shown in these tables, indicate two general tendencies. They are the higher variability of the experimental animals in Trials 21-32 and lower variability in earlier trials. There are two important exceptions: (*a*) Series N and O, well-fed animals, show no differences in variability, whereas the highly motivated animals, Series D and E, showed

TABLE 66

COEFFICIENTS OF VARIATION FOR TOTAL DISTANCE AND TOTAL TIME SCORES FOR SERIES B AND C

MAZE 4

Trials	Distance B*	Distance C	Time B	Time C
9-12	1.50	8.63	1.00	1.75
13-16	.69	1.44	.63	.42
17-20	1.48	1.95	1.68	.57
21-24	.73	.49	.47	.26
25-28	.65	.45	.36	.17
29-32	.53	.46	.24	.24

*Series B was the experimental group.

TABLE 67

COEFFICIENTS OF VARIATIONS FOR TOTAL DISTANCE AND TOTAL TIME SCORES FOR SERIES D AND E

MAZE 1

	Distance		Time	
Trials	D*	E	D	E
9-12	2.14	1.77	2.02	.59
13-16	1.31	1.38	.74	.72
17-20	1.02	.50	.59	.43
21-24	.91	.47	.50	.27
25-28	.74	.33	.42	.23
29-32	.95	.31	.45	.26

*Series D was the experimental series.

TABLE 68

COEFFICIENTS OF VARIATION FOR TOTAL DISTANCE AND TOTAL TIME SCORES FOR SERIES N AND O

MAZE 1

	Distance		Time	
Trials*	N†	O	N	O
13-16	.95	.79	.65	.37
17-20	.85	.81	.78	.34
21-24	.58	.74	.62	.75
25-28	.43	.64	.55	.47
29-32	.66	.60	.60	.44
33-36	.56	.59	.23	.29

*The mean for Trials 9-12 was selected in this case, because the mean for Trials 5-8 was unusually high due to two very exploratory runs.

†Series N is the experimental series.

TABLE 69

COEFFICIENTS OF VARIATION FOR TOTAL DISTANCE AND TOTAL TIME SCORES FOR SERIES F AND SERIES G

MAZE 1

	Distance		Time	
Trials	F*	G	F	G
9-12	2.15	2.75	1.31	.97
13-16	1.15	.75	.88	.80
17-20	1.08	.93	.65	.43
21-24	.96	.83	.62	.41
25-28	.44	.65	.35	.32
29-32	.62	.68	.50	.23

*Series F was the experimental series.

marked differences. The response patterns for Series D and N were significantly different. Series N made a much larger percentage of *a*-responses than Series D. And Series D made a much larger percentage of *a*-responses than Series N. If the standard deviations for Series D and N, as found in Tables 24 and 58, respectively, are compared, it will be seen that the standard deviations for Series D are twice as large as those for Series N at nearly all levels. Series E was also slightly more variable than Series O. Increased incentive, it appears, resulted in more confusion and greater differentiation in the experimental animals, but accelerated learning with a considerable reduction in general exploratory performance. (*b*) The most significant exception is in the coefficients for very young animals. In this experiment the differences between the controls and experimental animals indicate greater variability in later trials for the control series than for Series F. It seems from this that the condition of positive transfer means lower variability. In the main, the trend of the coefficients of variation points to greater variability under the condition of negative transfer but lower variability under the condition of positive transfer.

At any rate, the higher variability of experimental animals in later trials was due directly to two facts: (*a*) the superior learning of a few animals that seemed immune to interference and (*b*) the marked retardation of others. The superior learning of the few was undoubtedly due to positive transfer, as one should expect. If the retardation in others was due directly to

negatively transferred response patterns, then the higher variability of experimental animals was a function of negative transfer. This seems to be the case since there is a significant relationship between the negative transfer from previous experience and later learning as indicated in the correlations between the number of *a*-responses for each animal in early trials and the total distance scores for later trials. These are presented in Table 70.

It will be seen in the table that for experimental animals there was considerable relationship between the number of *a*-response-patterns in Trials 1-20 and the total distance scores for Trials 25-40. The relationship is even higher between the number of *a*-responses in Trials 1-20 and the total distance scores for complete learning, 108 trials. This relationship is much lower for control groups than for experimental groups. The

TABLE 70

RELATIONSHIP BETWEEN THE NUMBER OF RESPONSE PATTERNS *a* IN TRIALS ONE TO TWENTY AND THE TOTAL DISTANCE SCORES FOR LATER LEARNING DIFFICULT MAZES

Series	*N*	Trials	*r*	*P.E.*
Experimental				
A B D N	100	25-40	0.304	0.060
F	31	25-40	—0.197	0.115
N	14	25-40	0.617	0.111
N	14	5-108 (or complete learning)	0.829	0.056
Control				
C E O	57	25-40	0.201	0.085
G H	53	25-40	0.126	0.090
O	14	25-40	0.259	0.167
O	14	5-108 (or complete learning)	0.510*	0.132

*High due to position habits in two animals.

coefficients for experimental animals, with the exception of the very young animals, Series F, are more than five times their probable errors. It seems conclusive from these data that the conditions of increased variability were definitely related to the negative transfer from previous experience. This conclusion agrees with the findings on variability in learning easy mazes, and with the findings on variability for learning at different levels of practice. The increased variability of experimental animals at different levels of practice became more pronounced for total learning. The increased variability was the result of retarded learning in the experimental animals due to negative transfer from previous experience.

VIII

SUMMARY

Differences in Response Patterns Due to Interference

The data from the several experiments with transfer from easy to difficult mazes indicate two different changes in response patterns that resulted from interference. (*a*) When there was a definite, moderately economical outlet in the second learning situation for a previously acquired response pattern, the interference consisted of the persistence in that previously acquired habit. (*b*) When the second situation was similar to the first, but provided no definite outlet for the previously acquired habit, either because of mechanical limitations, or the interference of other maze experience, then the interference consisted of confused reactions and exploratory behavior with large distance and time scores. The status in this case was similar to that of learning a new habit. The evidence in support of the former consisted of significantly larger mean total scores for *a*-responses by experimental animals than by controls. The results from five different experiments including experiments with very young rats show no exceptions. The controls made much larger percentages of responses *d* and *p* combined and, therefore, showed significantly better learning of the direction of food. The evidence for the second was the data from Experiment II*a*. The differences between the control and experimental animals in mean

total distance and time scores for 28 trials were all significant. But there was no unobstructed definite response pattern from the previous learning that could be transferred directly in learning Maze 1. Consequently, the experimental animals made large percentages of uneconomical, exploratory responses with increased time per distance run.

Differences in Mean Total Distance and Mean Total Time Scores

The differences between the experimental and control animals in mean total distance and mean total time scores varied with the presence of other factors and the measurement made. In learning difficult mazes under the condition of interference the older experimental animals showed positive transfer effects in the first divisions of trials, but negative transfer effects in Trials 25-40. The mean total scores for 40 trials, and even for Trials 5-40, indicated, therefore, no considerable differences and no consistent direction of the transfer. But the differences between the experimental animals and controls in Trials 25-40 and in complete learning of difficult mazes, with only one exception, showed negative improvement for experimental animals. In the case of easy mazes with antagonistic true paths, the differences in mean total scores for distance, time, and trials for complete learning indicated negative transfer, without exception, for older animals.

The differences between experimental and control animals in the mean total scores for later divisions of trials and for total learning depended very probably upon the favorableness of the conditions of learning.

In Experiment III the diet was both quantitatively and qualitatively stinted as compared with the diet used in later experiments. Since this was the only difference in procedure and animals between Experiments III and VIII, the differences in learning and negative transfer were probably due to that difference in procedure. The learning by the control animals in Experiment III was much superior to that of the control animals in Experiment VIII. The median number of trials for complete learning in the former was 42, but in the latter, 56. Stronger food incentive increased the rate of learning, especially in the controls. Consequently, the differences in Trials 25-40 were large and significant.

It should be noted that the differences between mean total scores for large divisions of trials, including especially the scores from beginning trials, are likely to be poor measures of interference. They represent simply the differences between the effects of positive and negative transfer. A better measure of interference is the measure of a status at the end of a long course of trials. The interference that is of any considerable consequence is more than a temporary disturbance. It is a persistent obstruction to a normal rate of learning. The presence of large percentages of *a*-responses in the performance of the experimental animals in the early part of learning was, except in very young animals, a certain indication that retarded relearning in later trials would be the outcome. But that retardation, because of other factors in the learning situation, might not appear in the differences between

mean total distance or mean total time scores until after 40 trials, as the results of Experiment VIII have shown. In any learning situation, if closely related previous experience does not effect an increased rate of improvement in learning, that fact should not be considered as evidence of no transfer effects. It should be considered as evidence of the presence of negative transfer. When the general practice effects were similar and the possibilities for interference in control learning eliminated, as was probably the case in Experiment II*a*, the differences between the control and experimental animals were large and significant, and the positive transfer in the control animals was pronounced. This means that in any learning situation the negating factors from previous experience should be determined and controlled as far as possible so that the full effect of previous experience might tend toward better learning.

Learning Plateaus

In all series of older experimental animals the rate of improvement in Trials 25-40 in learning difficult mazes and in later learning in all mazes showed distinct tendencies to learning plateaus. For the learning situations used in these experiments this was probably not evidence of permanently conditioned learning ability. In the relearning tests six days after completing the learning of the second maze and 40 days after the first relearning (using easy mazes), there was no evidence of the recurrence of interference in the experimental animals. By a method of gradual conditioning, moreover, the interference was overcome in a rather

normal distribution of trials. These data on the persistence of interference may not be conclusive, however, in view of the fact that only easy mazes were used, and in conditioning there was only a small number of animals. The practical effect, nevertheless, of persistent interference is conditioned learning with every appearance of mental dullness so far as measurements are concerned.

The presence of plateaus, or persistent interference, in some animals was probably not due to poor initial learning ability. The data available are not conclusive, but they give no support to that explanation. In the gradual conditioning of animals that had persisted in the interference pattern for 80 trials, learning was readily accomplished and the distributions of scores were as normal as they could probably be for the small number of cases used. In the case of very young rats, for which the first mazes gave good discrimination, the correlation between the total distance scores in the first, or interfering maze, and the number of *a*-response-patterns in the first 20 trials in the second maze was $-.191 \pm .116$. This coefficient of correlation is not significant evidence of relationship, but it shows, nevertheless, that negative transfer was probably not due to poor initial learning ability.

The persistence of interference was probably not due to chance position habits. The *a*-response-pattern was rarely fixated in control animals in spite of the fact that they started learning with considerable percentages of those responses. The best evidence, however, was the correlations of .522 for total distance scores and .57

for total time scores between interference learning in Maze 1 and interference learning in Maze 4. The animals that were disturbed in learning Maze 4 were likewise disturbed in learning Maze 1 in spite of the fact that in learning Maze 1 the *a*-response-pattern did not become the prevailing habit. The interference was due to more than a mere repetition of a succession of response elements.

Variability

The variability of experimental animals was, with few exceptions, higher both for complete learning and for different levels of practice. This was due (*a*) to the probable immunity of some animals from interference and (*b*) to the retarded learning resulting from persistence in the interference pattern. Although the reliability of the apparatus would not justify the conclusion that interference resulted in increased individual differences, nevertheless, the trend of the data is in that direction.

Age

In the case of animals learning the interfering habit in a very early stage of development negative transfer from first learning to learning the second maze (a difficult maze) resulted in large percentages of *a*-responses in the first few trials. But the interference broke down rapidly, with the result that the differences in mean total distance and time scores showed positive transfer. When both mazes were easily learned, the transfer effect was slightly negative. The chief difference between very young and older animals was in the per-

sistence of the negatively transferred response patterns. The cause for the break-down of the interference in very young animals is not clear. There was, however, a significant difference between very young and older rats in the learning of the first maze. Learning between the ages of 20 and 30 days was significantly poorer than learning after 50 days of age. This was true for all criteria. It seems conclusive that the cause of the rapid break-down of the interference in very young animals was intrinsic to the early developmental condition of the animals at the time of learning the interfering habit. Response patterns were less readily acquired and more readily disrupted in very young animals.

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L'EFFET DU CONFLIT DES HABITUDES SUR LE RENDEMENT DANS L'APPRENTISSAGE DU LABYRINTHE

(Résumé)

Ce rapport décrit huit expériences de l'apprentissage du labyrinthe avec 356 rats blancs. Dans chaque expérience on a mis en paires les labyrinthes (1) pour des stimuli semblables du labyrinthe, et (2) pour des réactions différentes ou en partie antagonistes. Le processus au cas des animaux expérimentaux pour cinq expériences a été en général le suivant: l'apprentissage complet d'un labyrinthe facile A, le repos pendant trois jours, le nouvel apprentissage d'A, le repos pendant trois jours, et quarante épreuves ou l'apprentissage complet d'un labyrinthe difficile B. Les animaux de contrôle n'ont appris que le labyrinthe B. Dans trois expériences on a substitué un labyrinthe facile C au labyrinthe B. Les données se sont composées du nombre d'épreuves, du temps de chaque épreuve, de la distance de chaque épreuve, et un tableau du rendement de chaque animal.

Les données indiquent les conclusions suivantes: (1) Dans plusieurs tests de la constance du rendement on n'a trouvé aucunes différences d'âge, mais les corrélations entre les résultats totaux de distance pour les différentes divisions des épreuves ont été plus élevées pour les animaux expérimentaux que pour les animaux de contrôle. (2) Quand le transfert positif entre deux labyrinthes semblables a été en grante partie compensé par l'apprentissage par "conflit," interpolé, les intercorrélations ont été de 0,52 pour les résultats de distance et de 0,57 pour les résultats de temps. (3) Pour de différents degrés du stimulant et du nouvel apprentissage et pour trois différents âges des animaux les différences des formes de réponse entre les groupes expérimental et de contrôle ont été toutes d'une façon signifiante en faveur d'un transfert négatif. Les animaux expérimentaux ont persisté en de beaucoup plus grands pourcentages des formes de réponse ce qui a réintégré les formes correctes de réponse pour le premier labyrinthe appris. (4) Les différences entre les animaux expérimentaux et ceux de contrôle dans les résultats de distance des épreuves postérieures ont été toutes constamment et quelques-unes d'une façon signifiante en faveur d'un transfert négatif chez les animaux plus âgés. (5) Les résultats de temps ont donné des différences signifiantes en faveur d'un transfert négatif chez les animaux plus âgés seulement, et seulement quand les effets d'un transfert positif général ont été probablement semblables pour les deux groupes des animaux, ou quand on a rendu plus rapide l'apprentissage par un haut degré d'un stimulant de nourriture. (6) Des périodes de 8 à 20 épreuves avec peu ou nulle amélioration dans les résultats de temps et de distance ont caractérisé l'apprentissage des animaux expérimentaux plus âgés. Ces plateaux ont été vraiment dus à la persistance des formes de réponse transférées de l'apprentissage antérieur. (7) Quand il n'y a eu aucun moyen défini d'échappement dans la deuxième situation d'apprentissage pour les formes de réponse acquises antérieurement, les animaux expérimentaux ont été très dérangés et les proportions des résultats de temps et ceux de distance ont été plus élevées que chez les animaux de contrôle. (8) L'apprentissage des simples habitudes du labyrinthe pendant la période entre 20 à 30 jours de l'âge a été beaucoup pire qu'après l'âge de 40 jours. (9) On n'a obtenu aucune différence signifiante entre les animaux de contrôle et les expérimentaux dans les résultats de distance et de temps dans l'apprentissage des labyrinthes B et C quand l'habitude de "conflit" a été acquise pendant la période entre les âges de 20 et de 30 jours. Dans l'apprentissage du labyrinthe B l'influence des habitudes de conflit acquises à un âge très peu

avancé s'est perdu si rapidement qu'il a résulté une balance en faveur d'un transfert positif. (10) Les variabilités absolue et relative ont tendu à être plus élevées pour les animaux expérimentaux que pour ceux de contrôle. (11) Les expériences avec les labyrinthes A et C montrent que la différence de difficulté des labyrinthes A et B n'aurait été de nulle importance comme facteurs dans le transfert négatif.

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DER EINFLUSS DES WIDERSTREITS DER GEWOHNHEITEN AUF DIE TÄTIGKEIT BEI DEM ERLERNEN EINES LABYRINTHES

(Referat)

Dieser Bericht umfasst 8 Lernexperimente mit Labyrinthen an 356 Albinoratten. In jedem Experiment wurden die Ratten gepaart (1) in Bezug auf ähnliche Labyrinthreize und (2) in Bezug auf verschiedene oder zum Teil antagonistische Reaktionen. Das Verfahren mit den Versuchstieren in 5 Experimenten war im Allgemeinen folgendes: völlige Lösung eines leichten Labyrinthes, A; (3) Tage Ruhe; Wiedererlernen von A; und 40 Versuche an, oder völliges Erlernen von, einem schweren Labyrinth, B. Die Kontrolltiere erlernten nur das Labyrinth B. In 3 Experimenten wurde das Labyrinth B durch ein leichtes Labyrinth, C, ersetzt. Die gesammelten Data waren folgende: Die Zahl der Versuche, die Zeitlänge in jedem Versuch, die in jedem Versuch zurückgelegte Strecke; und eine Tabularizierung des Laufes (run) von jedem Tier.

Die Data liefern folgende Befunde: (1) In mehreren Versuchen über die Beständigkeit der Tätigkeit (consistency of performance) zeigten sich keine Altersunterschiede, aber die Korrelationen zwischen den Gesammtdistanzzahlen (total distance scores) in verschiedenen Abteilungen der Versuche waren bei Versuchstieren höher als bei Kontrolltieren. (2) Wenn der positiven Übertragung (positive transfer) zwischen zwei ähnlichen Labyrinthen grossenteils durch interpolliertes, störend einwirkendes Lernen (interference learning) entgegengewirkt wurde, waren die Interkorrelationen an den Distanzzahlen (distance scores) .52 und an den Zeitlängezahlen .57. (3) In Bezug auf verschiedene Grade des Reizes und des Überlernens (over-learning) und bei drei verschiedenen Altern der Tiere standen die Unterschiede in in den Reaktionsformen (response patterns) zwischen den Versuchs—und den Kontrollgruppen alle zu Gunsten der negativen Uebertragung. Die Versuchstiere beharrten in viel höheren Prozensätzen von Reaktionsformen, welche die Reaktionsformen, die in dem zuerst erlernten Labyrinth richtig gewesen waren, wiederholten. (4) Die Unterschiede zwischen Kontrolltieren und Versuchstieren in Bezug auf Distanzzahlen späterer Versuche standen alle konsequent und manche bezeichnend (significantly) zu Gunsten der negativen Uebertragung bei älteren Tieren. (5) Die Zeitlängezahlen ergaben bezeichnende Unterschiede zu Gunsten der negativen Übertragung nur bei älteren Tieren, und dann nur wenn die allgemeinen Uebertragungswirkungen wahrscheinlich in den beiden Tiergruppen ziemlich gleich waren, oder wenn das Lernen durch sehr starken Nahrungsreiz (food stimulus) beschleunigt worden war. (6) Das Lernen bei älteren Versuchstieren wurde charakterisiert durch Perioden sich erstreckend über 6 bis 20 Versuche während welchen wenig oder gar keine Besserung der Leistung stattfand. Diese Plateauperioden (plateaux) hatten ihren Ursprung sicherlich in der Beharrung (persistence) in übergetragenen

(transferred) Reaktionsformen aus früherem Lernen. (7) Wenn die zweite Lerngelegenheit (learning situation) für die früher angeeigneten Reaktionsformen keine bestimmte Abzugsmöglichkeit (outlet) darbot, waren die Tiere sehr gestört, und das Verhältnis zwischen den Zeitzahlen und den Distanzzahlen war dann grösser, als bei den Kontrolltieren. (8) Das Erlernen von einfachen Labyrinth—gewohnheiten war während der Periode, in der die Tiere 20 bis 30 Tage alt waren, bedeutend schlechter, als im Alter von über 40 Tagen. (9) Wenn die störend einwirkende Gewohnheit im Alter von 30 bis 40 Tagen angeeignet worden war, zeigten sich im Erlernen des Labyrinthes B oder C keine bedeutende Unterschiede zwischen den Kontroll- und den Versuchstieren, weder in Bezug auf Distanz- noch in Bezug auf Zeitzahlen. Im Erlernen des Labyrinthes B versagte der Einfluss der störenden Gewohnheiten, die angeeignet worden waren, als die Tiere noch sehr jung waren, so rasch, dass ein Überschuss zu Gunsten der positiven Übertragung verursacht wurde. (10) Sowohl die absolute wie die relative Variabilität war, im grossen Ganzen, bei den Versuchstieren etwas höher als bei den Kontrolltieren. (11) Die Versuche mit den *Labyrinthen A und C zeigten, dass die Unterschiede zwischen den Labyrinthen* A und B in Bezug auf Schwierigkeit als Bestandteile einer negativen Übertragung wahrscheinlich ohne Bedeutung waren.

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